Attachment I

Marine Geological Investigations in the Beaufort Sea in 1981 and Preliminary Interpretations for region from the Canning River to the Canadian Border.

By: Erk Reimnitz, Peter W. Barnes, Peter W. Minkler, Douglas M. Rearic, Edward W. Kempema, and Thomas Reiss.

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INTRODUCTION

The USGS vessel R/V KARLUK ran approximately 1000 km of geophysical tracklines on the inner shelf of the Beaufort Sea, Alaska from July 14 to August 20, 1981. In addition to the trackline surveys, 37 sediment grab samples were collected, one area was investigated by SCUBA divers, and 5 sites were monitored with Ocean Bottom Seismographs (OBS), three per site. The R/V KARLUK left the Beaufort Sea on August 20 to support investigations by Drs. Ralph Hunter and Larry Phillips in the Chukchi Sea.

In our 1981 field efforts, the emphasis was on reconnaissance data collection from the eastern sector, between the Canning River and the international border. This work was accomplished in two legs, the first one under P.W. Barnes, the second under Erk Reimnitz. Ice and weather conditions were about average to favorable for inner shelf navigation during the first half of the available open-water season. In this report we outline the general scope of our 1981 field efforts in the Beaufort Sea, the types of equipment used, list much of the data gathered, present those parameters already extracted from the geophysical records, and give preliminary interpretations of our findings.

DESCRIPTION OF FIELD OPERATIONS

Reconnaissance work - Our primary goal, a reconnaissance survey from the Canning River to the Canadian border, where almost no inner shelf data is available, was accomplished (see Fig. 1). Geophysical lines were run as far offshore as ice concentrations allowed. All lines from the Canning River eastward extend seaward into very tight pack ice, beyond which further penetration was impossible. Early in the season this tight pack ice was near the coastline. As the season progressed, lines could extend farther seaward. One bay and one lagoon were surveyed along this shore. Thirty-seven grab samples were collected, mainly on the open shelf. For this reconnaissance work navigational control is based on radar fixes and dead reckoning. The probable uncertainty in position ranges from 100 or 200 m near shore, to as much as 3 km under dead reckoning on the seaward ends of several tracklines.

Site-specific work - Between the Canning River and the Colville River, surveys were site specific. Detailed surveys for preparation of side-scan sonar mosaics with bathymetry were run in four small areas, two on Stamukhi Shoal, one on the 18-m bench seaward of Narwhal Island, and another one on the 18-m bench seaward of Reindeer Island. Detailed bathymetric surveys were run around the "West DockC" and around two artificial gravel islands: Niakuk 3 and B.I?. 37. Two test lines from previous years were re-run (first run in 1973, see Reimnitz, et al., 1977; and Barnes, et al., 1978) and two new test lines were established with side-scan sonar to determine yearly rates of ice gouging. For all of these detailed surveys, positions were plotted using a

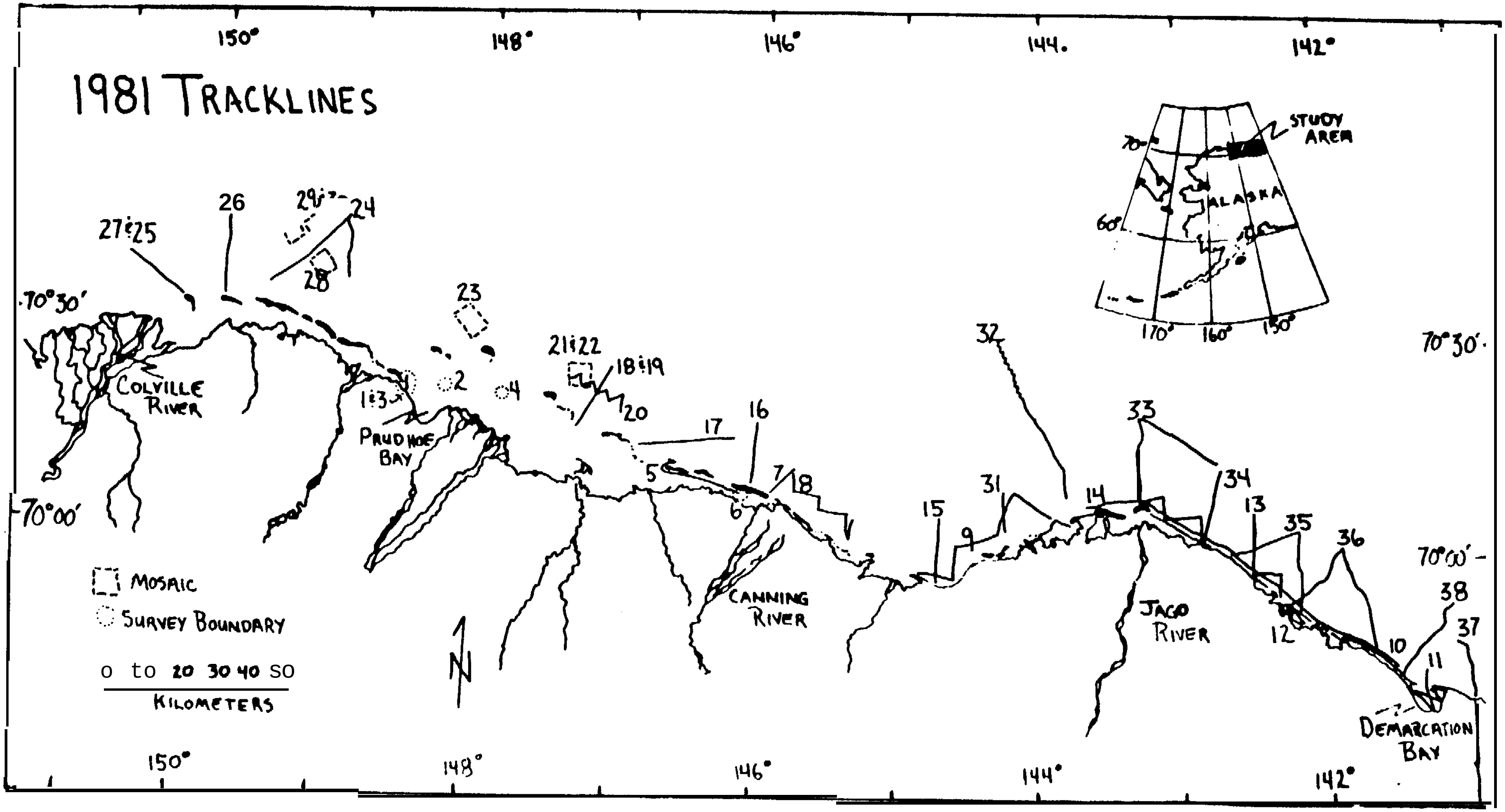

Figure 1. 1981 geophysical tracklines and site specific surveys, with line numbers listed in Table I.

Del Norte Trisponder system with a distance measuring accuracy of ±3 m. This system provides a position accuracy of ±8 m.

Miscellaneous studies - Three ocean bottom seismographs were deployed overnight at five different localities in shallow water between longitude 148° West and the Canadian border. The water depth ranged up to about 4 m. The purpose of this work was to monitor reported low-frequency natural seismicity in areas of decaying permafrost.

The diving investigation consisted of a roughly 1.5 km dive sled traverse through the area of the North Stamukhi Shoal side-scan sonar mosaic. A transponder was placed on the sea floor on each end of the traverse to facilitate rerunning of the ship- and diving surveys in later years. A large area around each transponder was seeded with lead birdshot for follow-up studies of sedimentation and shoal migration.

EQUIPMENT USED

Bathymetry was recorded on a Raytheon RTT 1000 dry paper recorder using either a hull-mounted 200 kHz transducer with an 8° beam width, or a 200 kHz transducer with a 4° beam width (narrow beam). All records were corrected for draft of vessel or tow depth. A 7 kHz transducer was used in conjunction with the RTT 1000, recording subbottom reflectors up to 10 m below the sea floor. Deeper penetration high-resolution seismic data were recorded on an EPC model 1400 recorder using 1/4 second sweep and firing rate with a 300 Joule EG&G Model 234 Uniboom as a sound source. The signal was filtered to approximately 600-1600 Hz.

Side-scan sonar records were taken using a Model 259-3 EG&G wet paper system and a Model 272 sonar fish with a 105 kHz 1/10 second pulse at a 20° beam angle depression. Records were also taken on a Model SM 960 EG&G digital system. The digital data for the mosaics were recorded on magnetic tape on a Kennedy Model 9000 magnetic tape recorder. The Model 272 sonar fish was used for both systems--the digital and the wet paper recorders.

OBS data were recorded on a 3-receiver system designed and built by Polar Research Laboratories of Santa Barbara, California. The three units were deployed in triangular arrays at each of 5 sites, with an internal spacing of about 100 m.

DATA ACQUIRED

Geophysical data acquired (see table 1) consist of approximately 1005 km of trackline bathymetry along with 7 kHz subbottom profiles, 800 km of side-scan sonar records, and 500 km of Uniboom seismic reflection records. The data listed in table 1 are keyed to figure 1. The data are in the form of 29 rolls of bathymetry, 20 rolls of side-scan sonar, 10 rolls of Uniboom records, 5 rolls of Simrad fathometer records, 38 reels of recorded side-scan magnetic tape, 120 hours of OBS magnetic tape, 8 field maps, and the ship's log. The ship's log contains important information on systems in use on each line, system settings (scale, filters, etc.), navigational data used in plotting positions, severity of ice conditions and course-holding problems and unique observations or systems difficulties. Copies of all field data are available on microfilm from the National Geophysical and Solar Terrestrial Data Center, NOAA, Boulder, Colorado. The microfilm is a copy of the geophysical records,

Table 1 - Geophysical data*

Line No.	Description	Raytheon	Side-scan	Uniboom	Kilometers
1	West Dock	yes	--	--	22
2	Niakuk Island	1	--	--	10
3	West Dock	1	--	--	22
4	Exxon Island	2	--	--	7
5	Outside Leffingwell Lagoon	2	--	1	24
6	Flaxman Island channel	2	--	1	6
7	Outside Flaxman Island	3	1	--	9
8	West Camden Bay	3	1	--	17
9	East Camden Bay	4	2	1	56
10	East of Jago Spit	6	5	--	81
11	Demarcation Bay	7	6	2	30
12	Beaufort Lagoon	8	7	3	17
13	Outside Beaufort Lagoon	9	7	3	29
14	East of Jago Spit to Barter Island	10	8	4	43
15	Test Line 7	11	9	4	19
16	Test Line 8	12	9	5	17
17	East of Pole Island	12	--	--	26
18	Test Line 6	13	10	5	17
19	Reciprocal, Test Line 6	13	11	--	17
20	18-m bench delineation	14	--	--	28
21	Mosaic northeast of Narwhal Island	15	12	--	55
22	Continue mosaic	16	12	--	
23	18-m bench north of Reindeer Island	16	13	--	23
24	Cat Shoal	17	--	--	45
25	Test Line 1	--	13	--	10
26	Test Line 2	18	14	--	20
27	Test Line 1	18	14	--	19
28	South Stamukhi Shoal Mosaic	19	14	--	46
29	North Stamukhi Shoal Mosaic	21	16	--	
30	Rerun 1977 lines on Stamukhi Shoals	23	--	--	65
31	Camden Bay to Barter Island	23	--	6	9
32	Continental Shelf Run off Barter Is.	23	17	6	48
33	Seaward leg offshore east of Barter Island (+ 14 km run over)	25	18	7	20
34	Shoreward leg east of Barter Island	26	18	7	19
35	Dogleg offshore & back into Pogok Bay	26	19	8	41
36	Offshore and back outside Beaufort Lagoon	27	19	8	52
37	Line at U.S./Canadian Border	29	20	9	19
38	Offshore Demarcation Bay	29	20	10	24

*Numbers in the Raytheon, side-scan and uniboom columns represent beginning roll numbers and signify data gathered on that line by that system. No number means the system was off.

ship's log and computer print-out of digitized way points. The printout of these way points would allow for reproduction of tracklines at any scale, and correlation to geophysical records through time points. Originals are archived at the U.S. Geological Survey, Deer Creek Facility, 3475 Deer Creek Road, Palo Alto, California 94304.

Surface samples collected are listed in table 2, along with water depth, longitude, and latitude, and shipboard sample descriptions and observations. The locations are shown in figure 2. Almost all samples were obtained with a grab, and cuts from most were given to Dr. Bill Briggs for studies of Ostracodes. The bulk of the material is being kept at our facility in Palo Alto, California.

DATA ANALYSIS

In our analysis of the geophysical reconnaissance data obtained between the Canning River and the Canadian border the focus has been on ice gouging. For the analysis we have basically used the shore-normal transects and eliminated shallow-water, shore-parallel lines (Fig. 3). The short time available for analysis required reduction of the number of parameters extracted from monographs and fathograms, compared to the very thorough analysis completed for the region west of the Canning River (Rearic et al., 1981). A copy of the completed data sheets used in this study is presented here as an Appendix. As in previous work, the tracklines are broken into 1-km-long segments, as listed in the first column of the data sheets. The parameters we considered most significant for this study are the following:

1. Water depth - to find relationships to severity of gouging.
2. Gouge depth - maximum gouge incision depth per km segment.
3. Ridge height - to allow calculation of total relief from gouging.
4. Gouge width - maximum per km segment.
5. Gouge density - the number of gouges actually counted is to the left of the normalized count listed in this column and separated by a slash.
6. Gouge orientation - dominant trend with respect to trackline is to the left of the true north orientations and separated by a slash.
7. Sediment cohesion - an attempt to judge from geophysical records whether the bottom is composed either of sand and coarser non-cohesive material, or of fine and cohesive material, as reflected in the shape and character, of the gouges.

We also measured the depth below sea level of the first continuous subbottom reflector seen on the 7kHz records ("Reflector A"). The main purpose of extracting this data was an attempt to relate ice gouges to the geology of the shelf surface. Subtracting water depth from "Reflector A" gives what we consider the maximum possible thickness of Holocene marine sediments blanketing the shelf. Given the fact that ice gouging has repeatedly disrupted the sediments since the last transgression, the Holocene marine sediments should not contain continuous internal reflectors in seismic records, an assumption that has strong support from detailed studies done in the Prudhoe Bay region. But until more detailed work allows us to correlate through the entire region of this reconnaissance survey, we cannot put much emphasis on this data.

TABLE 2

1981 Sample Descriptions

Station Number	Latitud	Longitude	Water Depth(m	Type Sample	Reference Location	Description
4	70.387°	148.515°	2	achunl	W. Dock	Core lenqth 37.5 cm. Verv thin souo on top overlying mud with-gravelly mud at-base. "
5	70.1050	145.3240	15.5	Grab	Line 8	On seaward flank of shoal. Sand
6	70.1040	145.3260	12.5	Grab	Line 8	On seaward flank of shoal. Clean sand
7	70.1030	145.328°	9.5	Grab	Line 8	On crest of shoal. Coarse sand
8	70.1020	145.3300	13	Grab	Line 8	Inside shoal. Coarse sand and pea gravel 1-2 cm) over grey mud.
9	70.1010	145.3330	13	Grab	Line 8	Inside shoal. Sandy mud. Few pebbles
10	70.0200	145.3150	n beach		:amden 8ay	Outcrop of stiff silty clay (?)
11	69.6750	141.3190	5	Grab	emarcation Bay	Sandy mud with bivalves.
12	69.6560	141.2810	4	Grab	Demarcation 8ay	Organic mud, silt and clay with trace of sand.
13	69.6550	141.3560	4	Grab	Demarcation Bay	Organic mud w/worm tubes.
14	69.8590	142.1630	2.2	Grab	eaufort Lagoon	Sandy organic-rich mud. Peaty material - brown. to black
15	69.8900	142.2530	3	Grab	eaufort Lagoon	Muddy organic sand
16	69.9090	142.3150	2.5	Grab	eaufort Lagoon	Muddy organic sand
17	70.1270	142.5000	35	Grab	)ffshore Pokok Bay	Muddy sand. Soft!
18	70.0560	142.4880	23.5	Grab	)ffshore Pokok Bay	Sandy mud
19	70.0310	142.5360	18.5	Grab	)ffshore Pokok Bay	"After 3 lowerings muddy gravel. Gravel w/benthic growth Stiff, silty clay below?
20	70.0170	142.5220	16	Grab	)ffshore Pokok Bay	Fairly clean sand overlain by 1-2 cm of muddy sediments.
21	i9 .9890	142.5180	7	Grab	)ffshore Pokok Bay	Clean fine sand

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TABLE 2

1981 Sample Descriptions

Station Number	Latitude	Longitude	Water Depth (m)	Type Sample	Reference Location	Description
22	70.633	148.1600	...	Ice	N. of Reindeer	Stamukhi ice
23	70.6330	148.1690		Ice	N. of Reindeer	Gravelly mud on only one surface of blocky ice floe.
24	70.620C	148.1270	18	Grab	18-m bench/Reindee	Crest of ridge. Muddy gravel, overconsolidated?
25	70.620C	148.1460	18	Grab	18-m bench/Reindee	Samples 24,25,26 at top of break in slope on 18-m bench all muddy gravel of various consistencies, from soupy on
26	70.620C	148.1670	18	Grab	18-m bench/Reindee	the west to stiff on the east.
27	70.498C	143.2030	52	Grab	Line 32	Gravel, up to 3 cm diameter w/bryozoans and other small growth in big gouge terrain with rounded relief. Between pebbles apparently is a trace of trapped transient mud.
28	70.357C	143.2920	40		Offshore Barter Is	Medium firm grey mud w/ a few scattered very small pebbles.
29	70.2300	142.7470	40	Grab	Offshore Pokok Bay	Firm mud w/ a 5-cm layer of soft mud on top. No shells or pebbles.
30	69.8730	141.7170	23	Grab	Line 36	Pebble rich, sandy mud, soft. Pebbles up to 5 cm w/coral growth, bryozoans.
31	59.8820	141.1470	34	Grab	Line 38	Soft mud, perhaps even transient layer separated by thin black line from finer mud below. No pebbles, probably no sand.
32	59.8850	'41.2420	32	Grab	Line 38	Slightly silty clay, increasing very gradually from soupy on surface to slightly firmer below. Several small shells, no pebbles.
33	59.8160	41.2590	30	Grab	Line 38	Silty clay, grey as sample 32 w/gradual increase in strength downward, no sand, small brittle star.
34	59.7860	41.3700	23	Grab	Line 38	Slightly pebbly, sandy mud. Soft at surface (5 cm) and firmer at bottom (15 cm).
35	69.7540	41.4440	6.5	Grab	Line 38	Pebbly, slightly muddy sand. One large pebble (6 cm), subrounded, with much growth, including bryozoans, coral, etc.
36	69.7390	41.4640	7.5	Grab	Line 38	Clean pebbly sand, one clast 6 cm. No growth, no mud.
37	69.7190	41.4790	7.5	Grdb	Line 38	After 3 lowerings: muddy gravel, clast to 10 cm, no growth.

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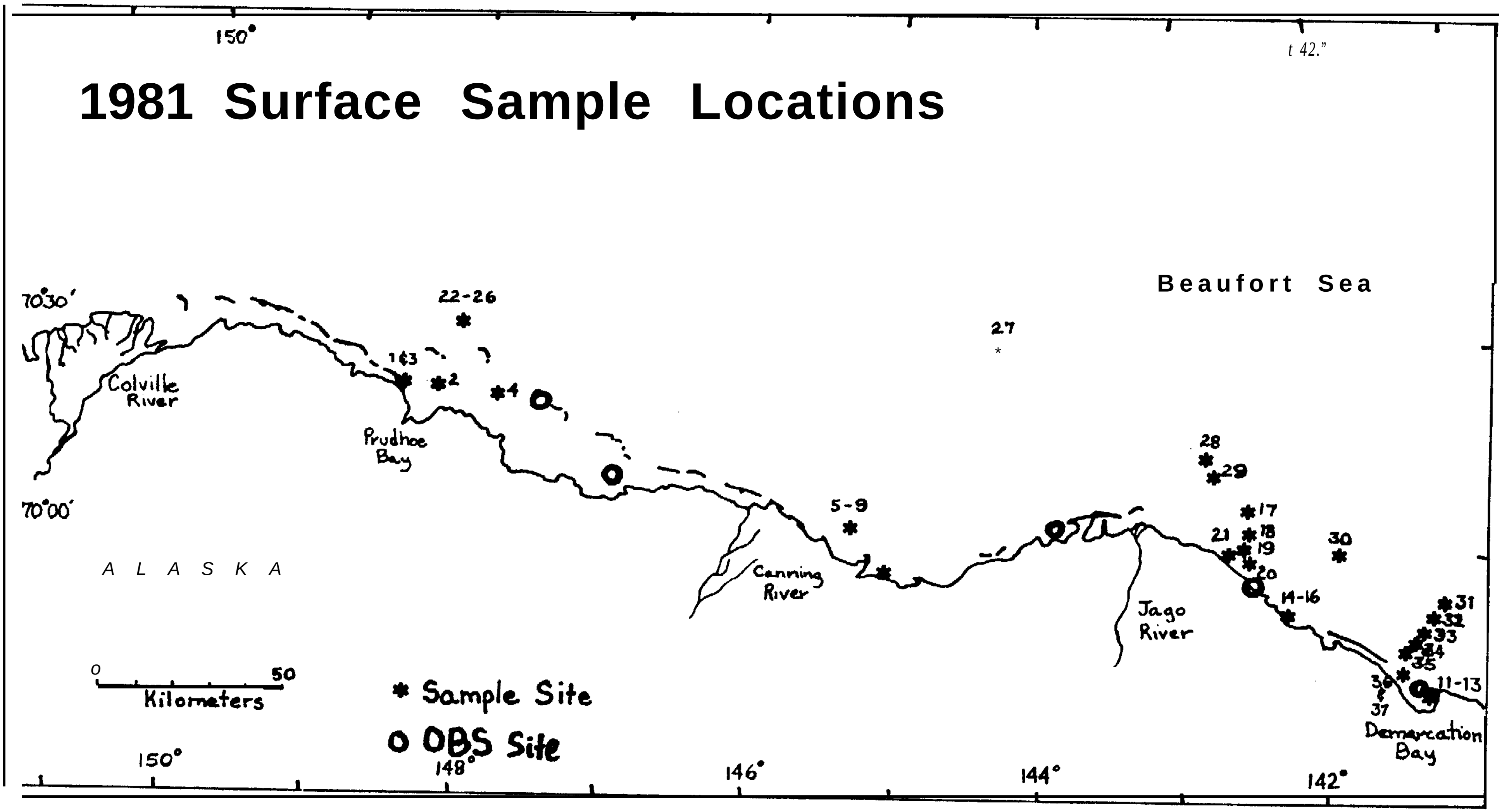

Figure 2. **1981** station locations for grab samples and Ocean Bottom Seismographs (OBS).

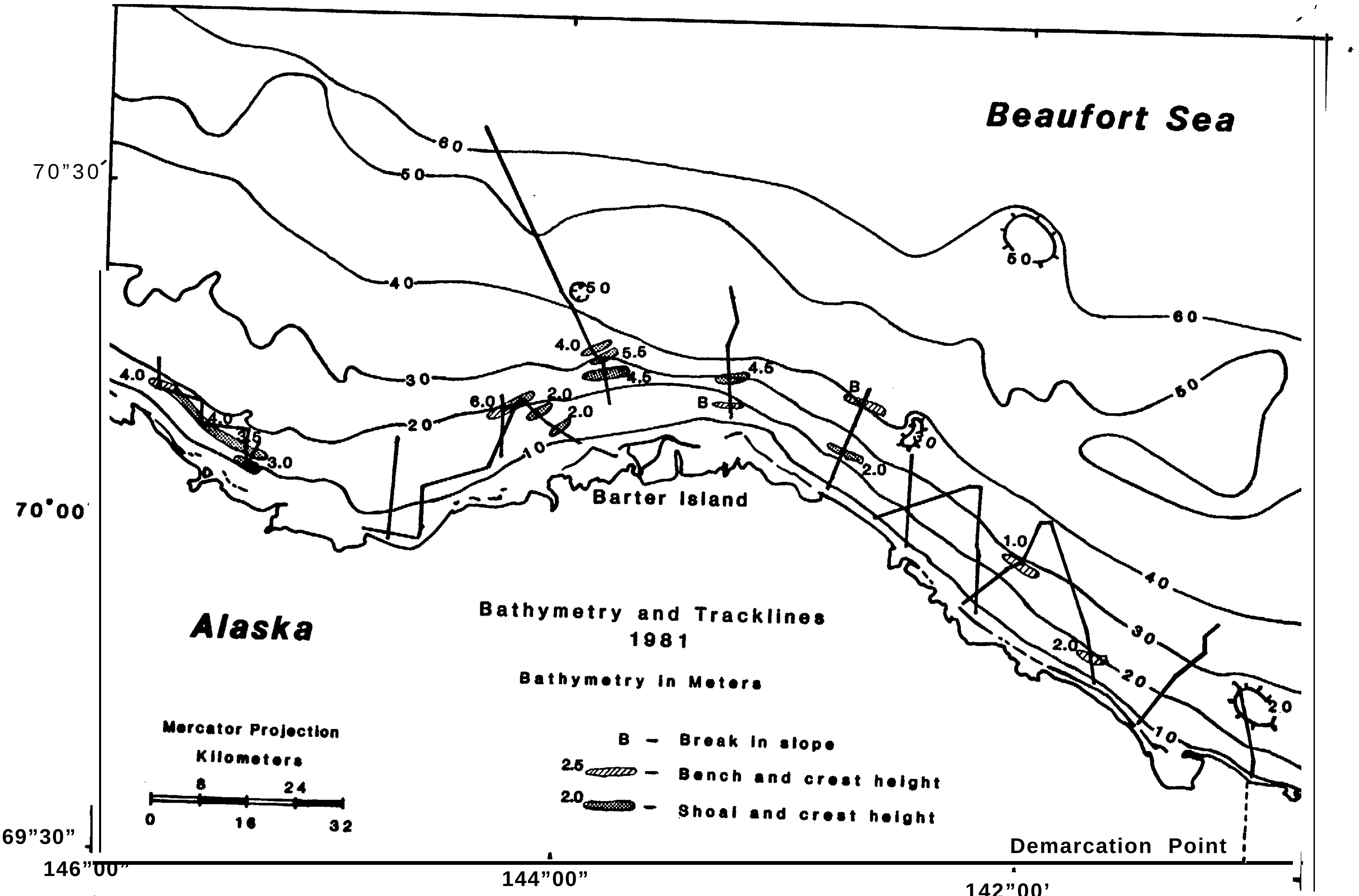

Figure 3.- Bathymetry and 1981 track lines used in the data analysis for the present study area. Shoals and benches, with their heights in meters above the surrounding sea floor, are shown.

A computer was used for plotting certain gouge parameters on maps, for simple statistical analyses, and for preparing scatter plots of gouge parameters.

RESULTS

Bathymetry - The bathymetry shown in figure 3 *is* from Greenberg, et al. (1980), and we generally found no major disagreements with the water depths recorded along our tracklines. However, the trackline off the Canadian border should have crossed a broad shoal suggested by published data, but we found no indications for this feature. Previous work has shown the important role played by shoals in ice dynamics and in controlling ice zonation (Rearic and Barnes, 1980; Reimnitz et al., 1978), and we therefore indicate the major topographic highs crossed by our survey lines, along with the height above the surrounding sea floor. We assume that these features are oriented generally shore parallel as suggested in figure 3. Only the shoal off the Canning River was surveyed by a zigzag trackline pattern and is well defined.
Ice Gouging - The pattern of dominant ice gouge alignment parallel to regional isobaths as mapped west of the Canning River (Barnes et al. , 1981) continues eastward to the Canadian border (Fig. 4). The Barter Island region, forming a major promontory jutting out into the pack-ice drift of the clockwise rotating Beaufort Gyre, separates two regions with distinctly different isobath trends and ice-gouge trends. In figure 5 we plotted water depth against dominant gouge orientation. A clear break is shown at 18-20 m water depth, with considerable orientation scatter shoreward, and parallel alignment seaward. The mean gouge orientation of 103"T in the study area is heavily weighted by trend determinations corresponding to the NW-SE trending isobaths east of Barter Island. By comparison, the mean gouge orientation west of the Canning River is 90°T.

Ice gouge density values (adjusted gouge counts per km of trackline) have been contoured in figure 6. A very well defined zone with over 150 gouges per km of trackline lies in water 18-36 m deep. This zone has been definedby Reimnitz et al. (1978) as the stamukhi zone. The scattergram (Fig. 7) shows a clear trend of increasing gouge densities from the shore to the stamukhi zone, and decreasing gouge densities from there to 58 m water depth. The greatest depth at which a gouge was seen was at 58 m on line 32, which extends to the edge of the shelf. The mean gouge density in the survey area is 108, compared to a value of 63 for the region west of the Canning River. We believe that these higher gouge counts are explained largely by the fact that mean water depth for the areas surveyed here is 25 m, whereas west of the Canning River the mean depth is 17 m.

The maximum gouge incision depths have been contoured in figure 8. Again the 18 m isobath is a dividing line between maximum incision depths of less than 1 m inshore and greater than 1 m offshore, as also shown on the scattergram in figure 9. But the maximum incision depths and the maximum gouge widths (Fig. 10) continue to increase seaward and do not begin to decrease until the very outer ice-gouge limit observed on lines 32 and 33. The mean for all maximum incision depths in the study area is .8 m, compared to .5 m for the western region. The mean of the maximum incision widths is 10 m, versus 8 m for the western region. Again the larger gouge size can be explained in part by the greater average water depth in the present study area.

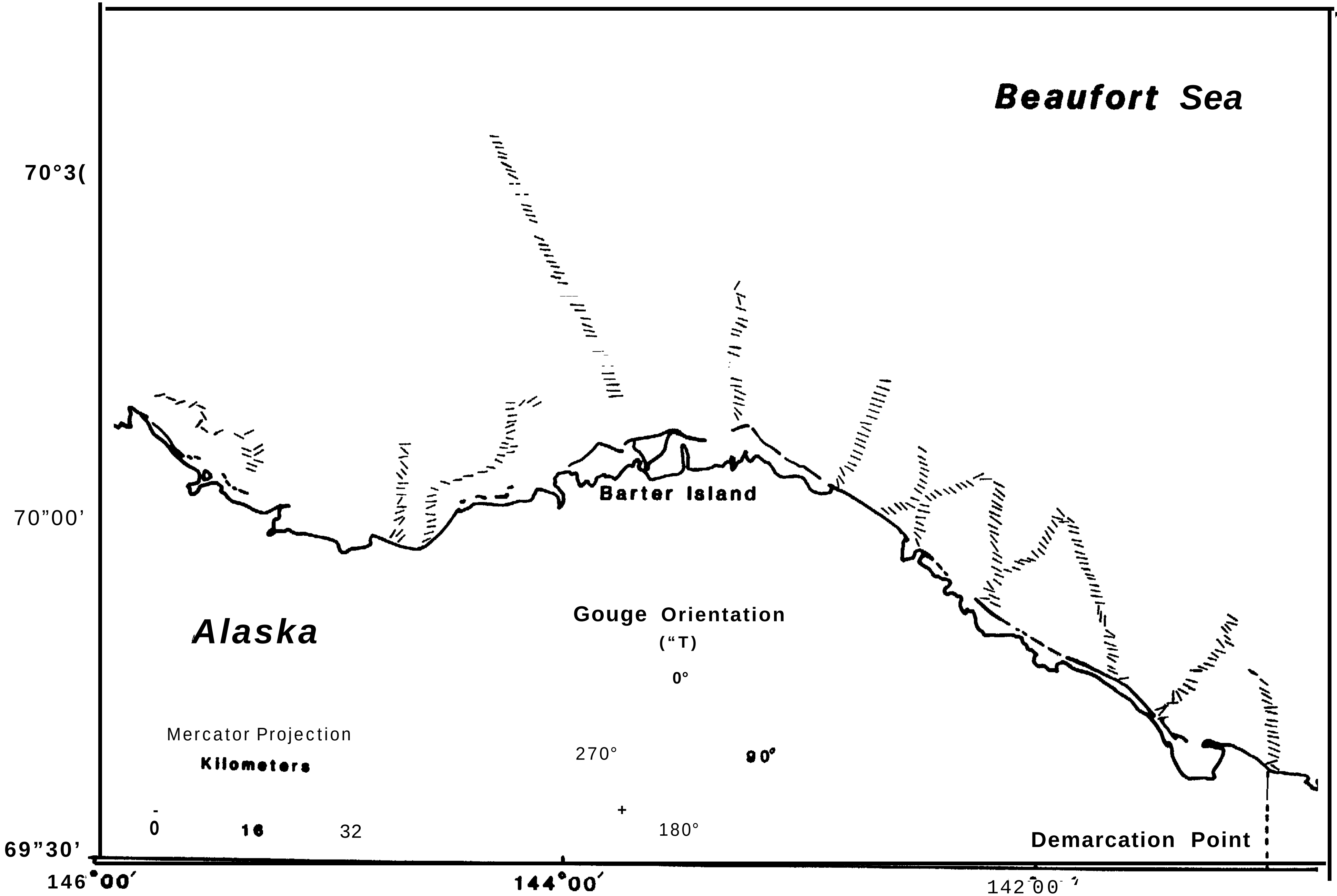

Figure 4.- Gouge orientations in the Barter Island area. Each line represents the dominant gouge orientation measured over 1 km of trackline.

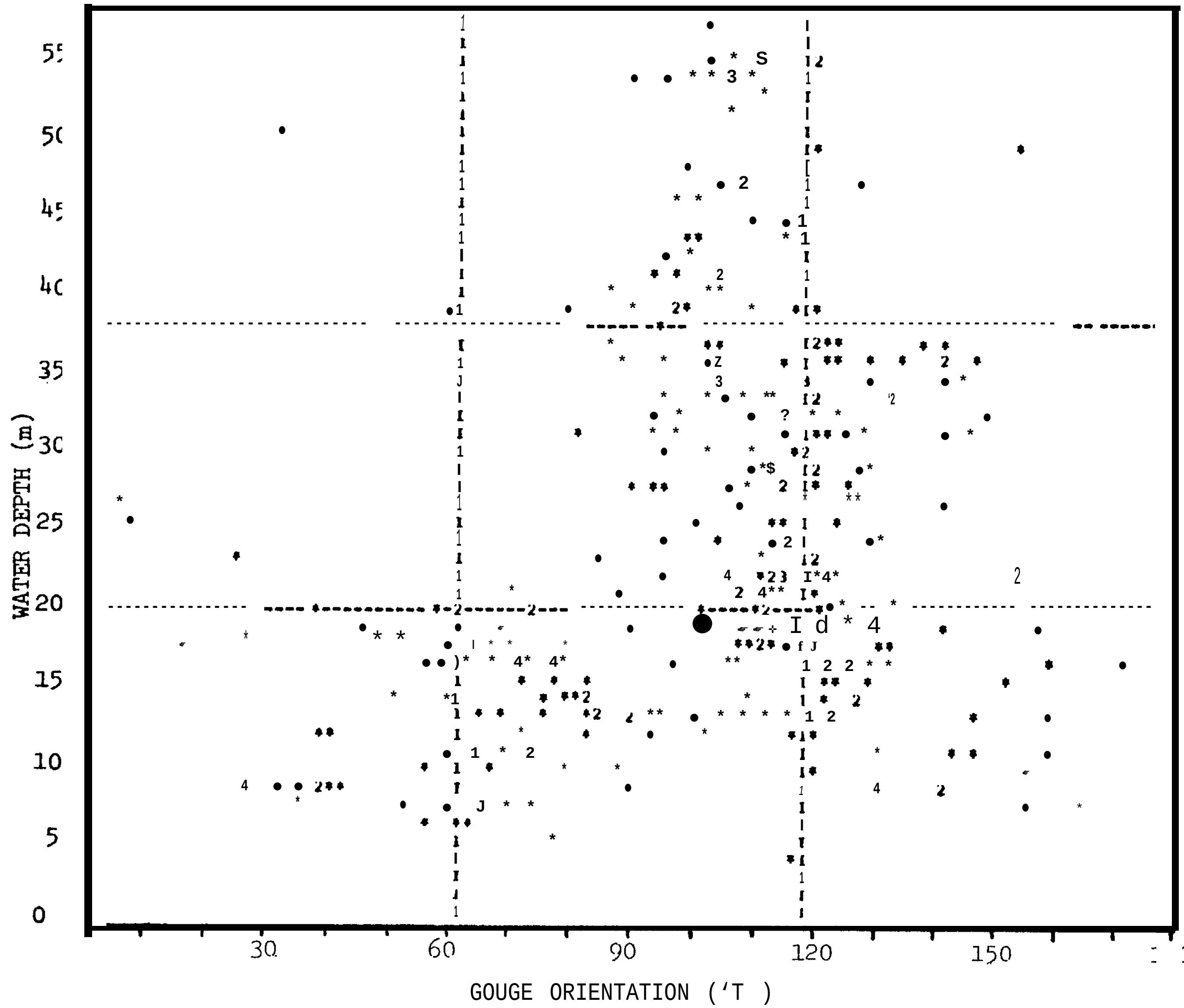

Figure 5.- Scattergram of gouge orientation versus water depth, showing wide scatter at water depths shallower than 18 meters.

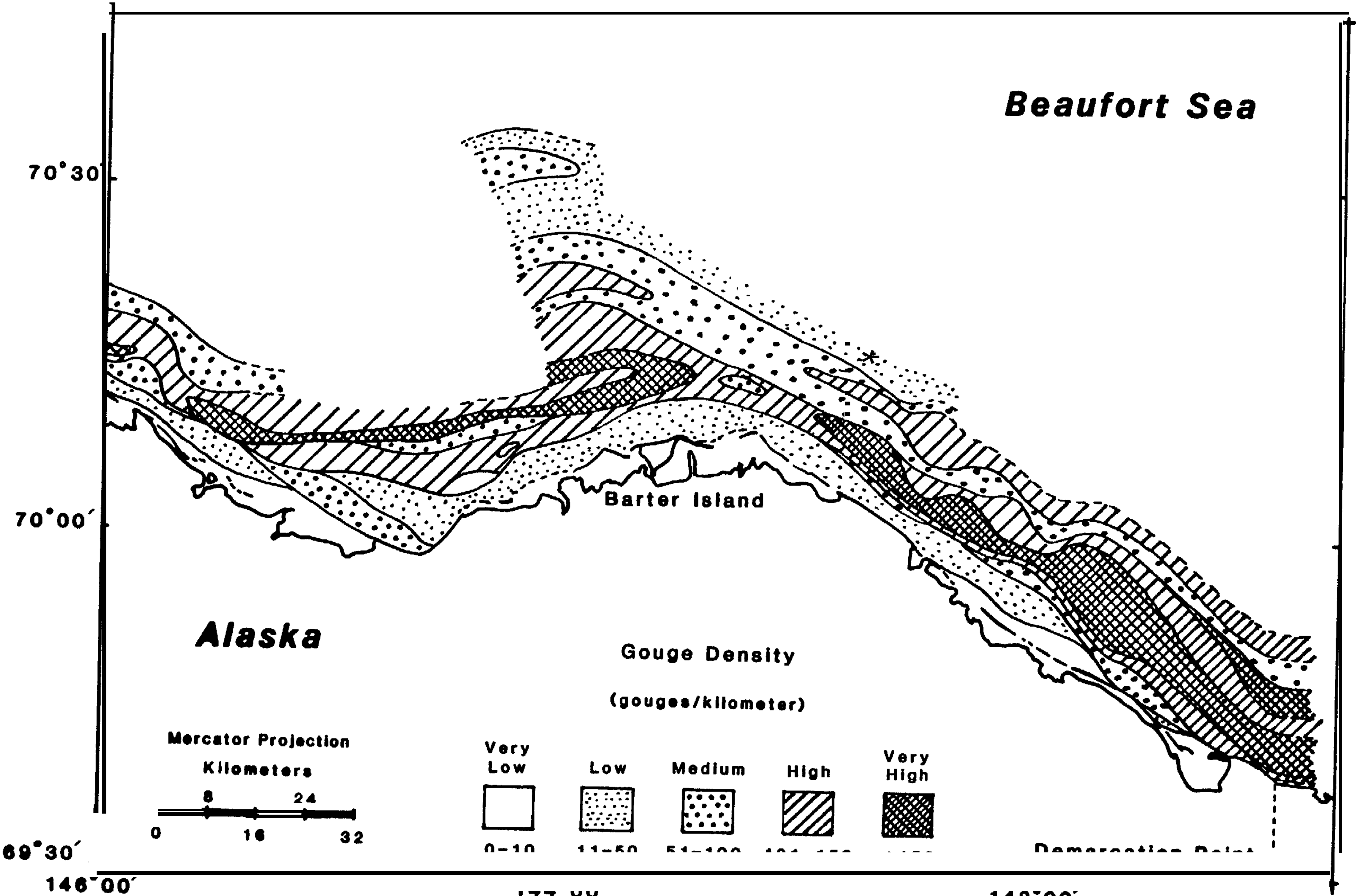

Figure 6.- Contours of ice gouge density values from Camden Bay to the Canadian border.

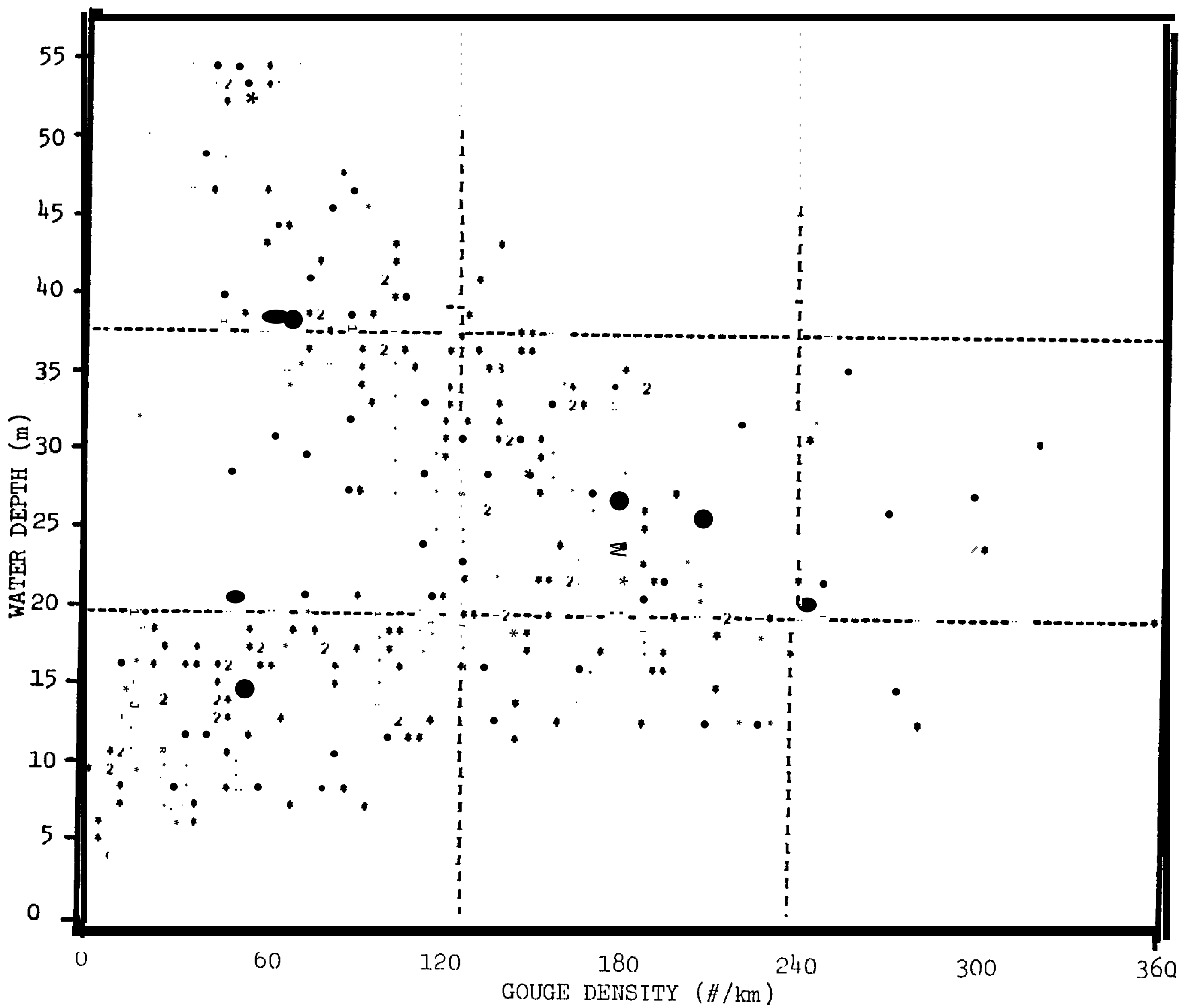

Figure 7.- Scattergram of gouge density versus water depth.

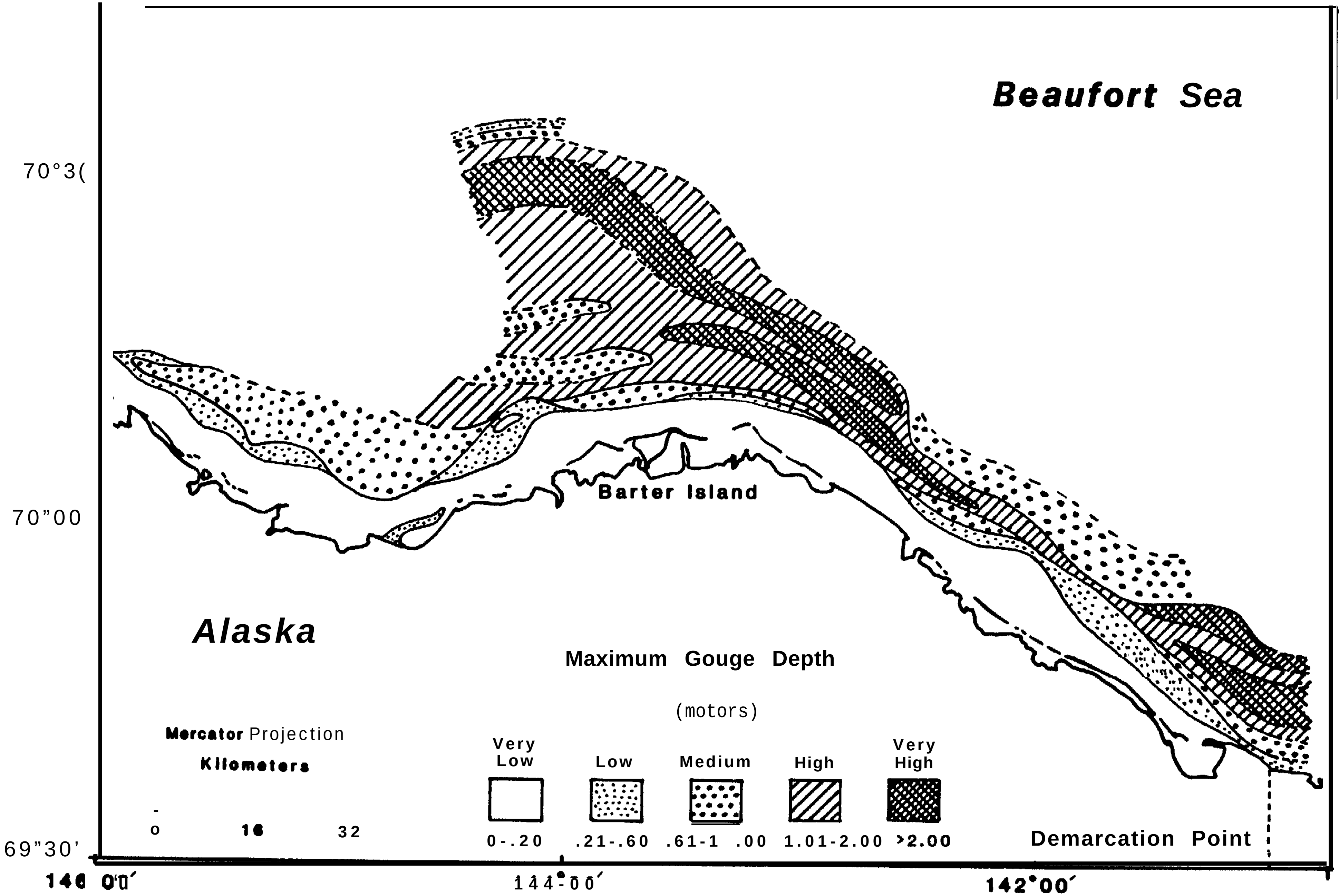

Figure 8.- Contour map of ice gouge maximum incision depth for the area from Camden Bay to the Canadian Border.

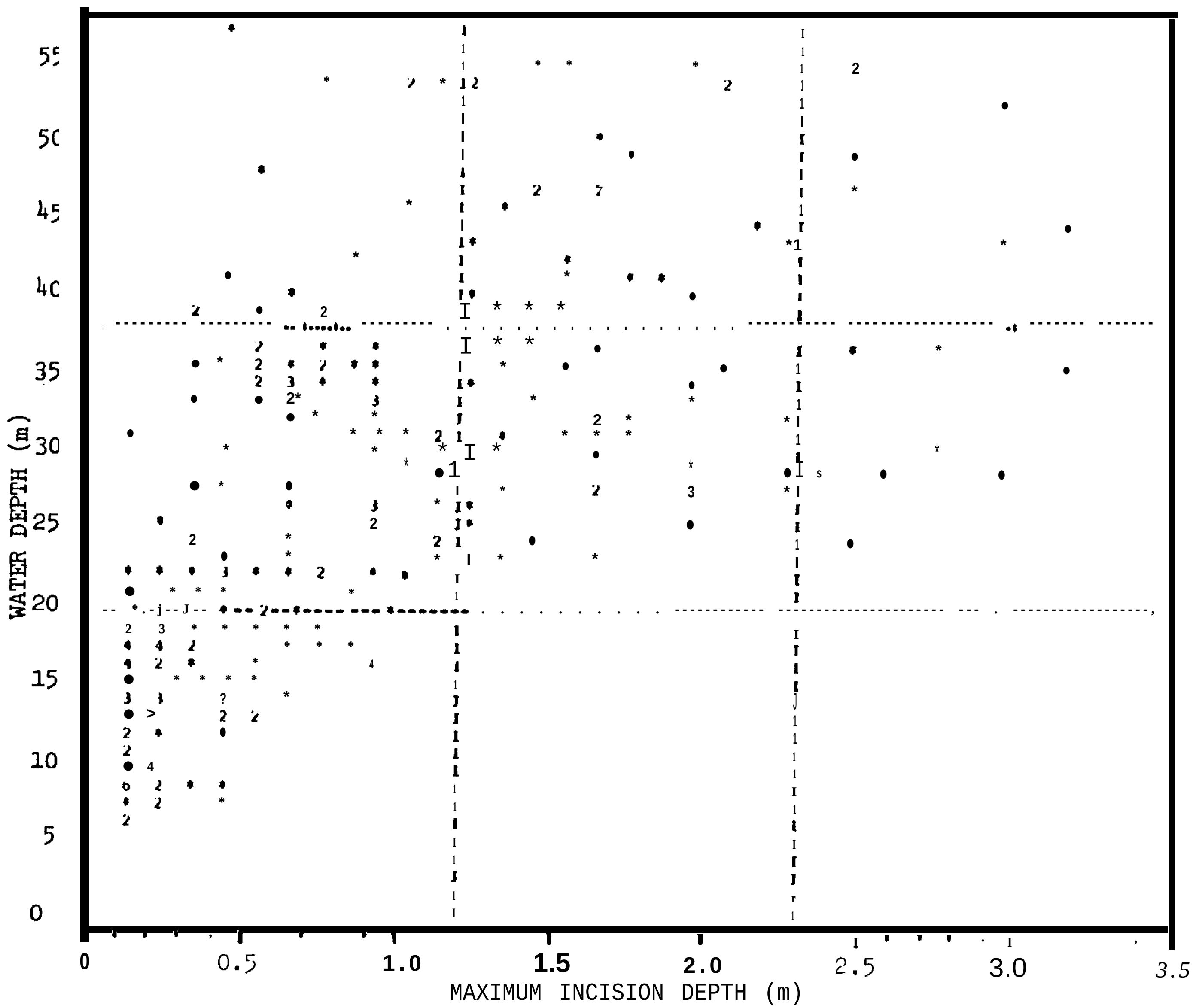

Figure 9.- Scattergram of ice gouge maximum incision depth versus water depth.

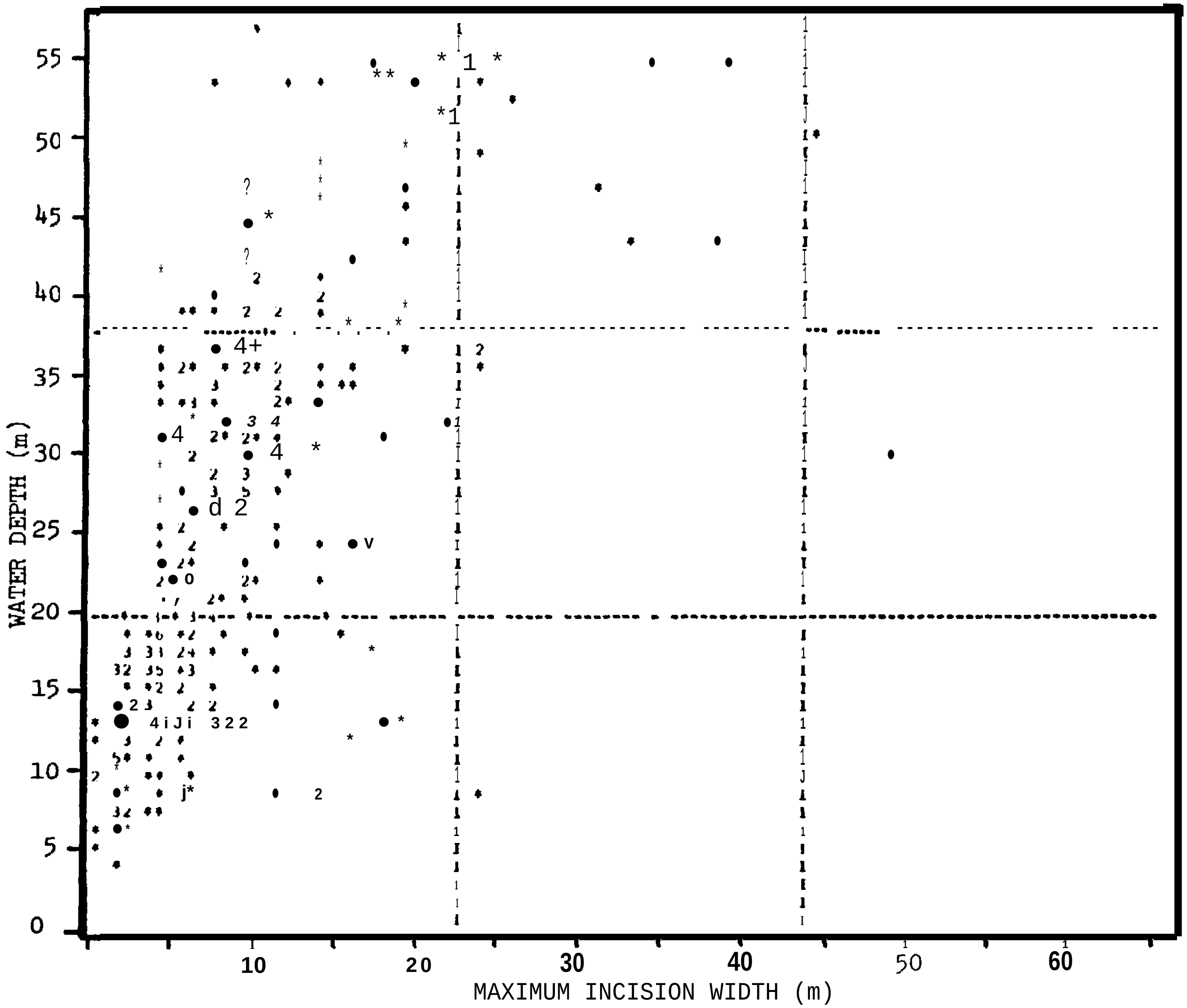

Figure 10. - Scattergram of ice gouge maximum incision width versus water depth.

Figure 11 is a scattergram of ridge height versus water depth. This shows that shoreward of the 18 m isobath ridges are no higher than 1 m. Ridges are highest between the 25-m and 45-m isobaths, and decrease from there seaward. This is contrary to the continuous increase in gouge depth and width measurements with increasing water depth. Total ice gouge relief (incision depth plus ridge height) was plotted against water depth in figure 12 and shows an increase offshore with a slight drop near the outer limit of ice gouging. Barnes et al. (1980), based on the highest ridges and greatest incision depths seen in the western area, speculated that total relief could reach 8 m in a single gouge. In the present study the greatest value for total relief seen in a single gouge was 8 m and found in water 38 m deep.

Figures 13 and 14 are scattergrams of gouge density plotted against maximum incision depth and maximum incision width respectively. Both scattergrams show that with increasing gouge density there is a corresponding decrease in gouge size. This inverse relationship canbe explainedby the fact that large gouges take up more space in each counting interval than smaller gouges and correspondingly fewer large gouges can be fit into such an interval. Many small gouges may also be reworked by formation of one large gouge. Figure 15 shows a plot of gouge orientation versus gouge density. The difference in scatter between figures 5 and 15 demonstrates that orientation is related to water depth but not to gouge density.

Seismic reflection studies - The central portion of the study area is interpreted by Grantz and Dinter (1980) as being tectonically and seismically active and undergoing uplift during the Holocene. The geology here is more favorable for seismic profiling than in most of the regions west of the Canning River, where the data is very difficult to decipher. Figure 17 is a sample Uniboom record (for location see figure 16) on which the most prominent sets of reflectors have been enhanced with inked lines. A major angular unconformity lies at a depth of 10-12 msec below the sea floor. Only 3 msec below the sea floor a discontinuous faint reflector can be traced. (Assuming a sound velocity of 2,000 msec in sediment, 1 msec is 1 m on this record.) Figure 18 is a sample Uniboom record with the angular unconformity at the sea floor possibly overlain by an extremely thin veneer of soft sediment that cannot be traced on this record. The hyperbolic patterns within the upper 10 msec of the record are a result of the ice gouge relief on the shelf surface. We do not know whether these gouges are cut into the old dipping strata truncated by the sea floor, or whether scouring by ice has resulted in a thin residual deposit in which the gouges are formed.

Very thin surface sediment layers are best resolved on the 7 kHz record. Examples of these records are shown in figure 19 (A and B). In figure 19B the strong dark band 1 m below the sea floor, and precisely conforming to the ice gouge relief, is the 7 kHz trace of the sea floor. The faint reflector at about 58 m below sea level is a real subbottom reflector. All such shallow reflectors were traced from the 7 kHz records at a very shortened horizontal scale, giving a high vertical exaggeration, and are presented as figures 20 through 23. Tracklines and figures are arranged *in* order from the Canning River to the Canadian border and all lines are oriented with the shoreward (S-SW) end on the left side, except tie line 33-34, which parallels the slope.

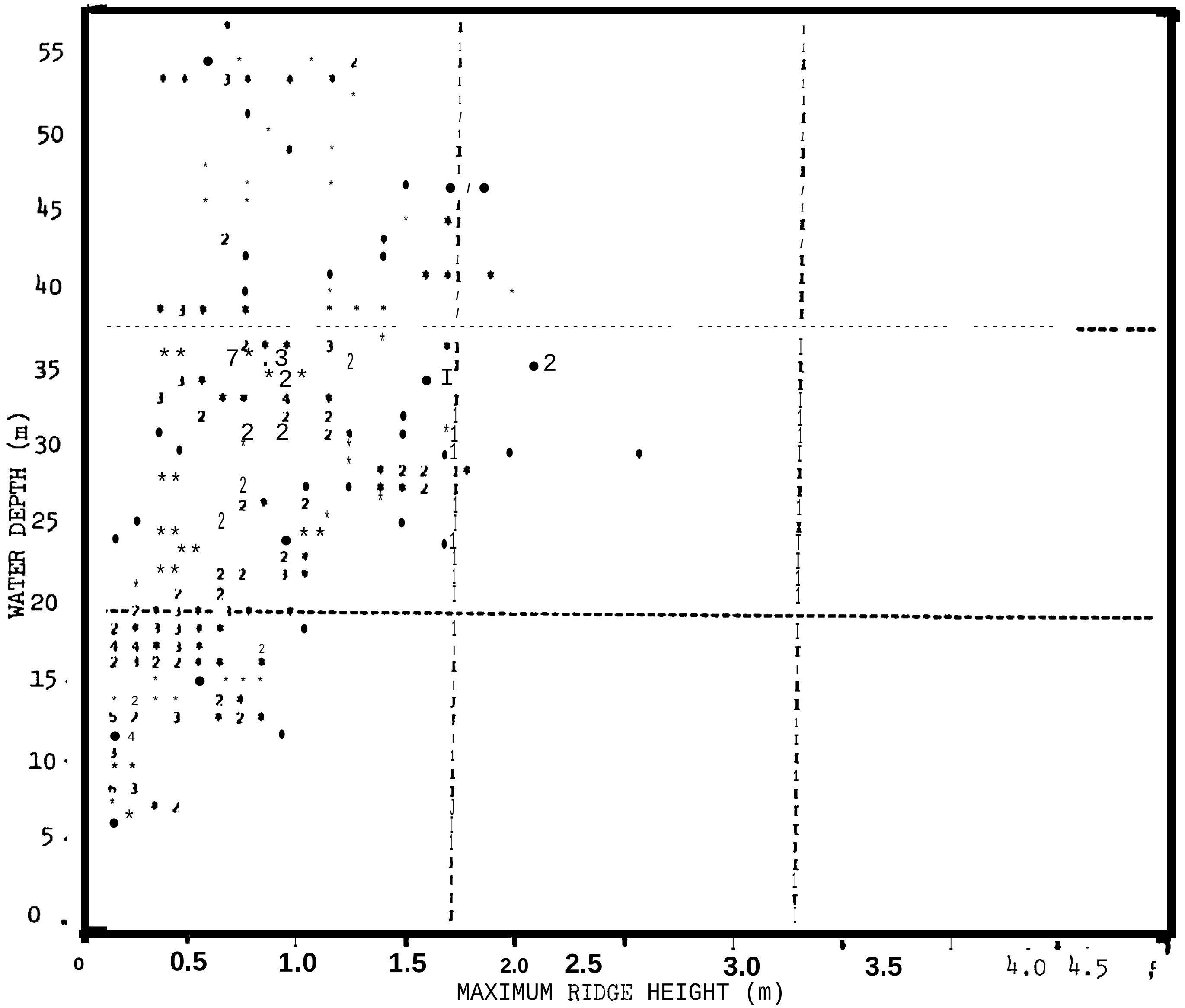

Figure 11.- Scattergram of maximum height of flanking ridges of gouges versus water depth.

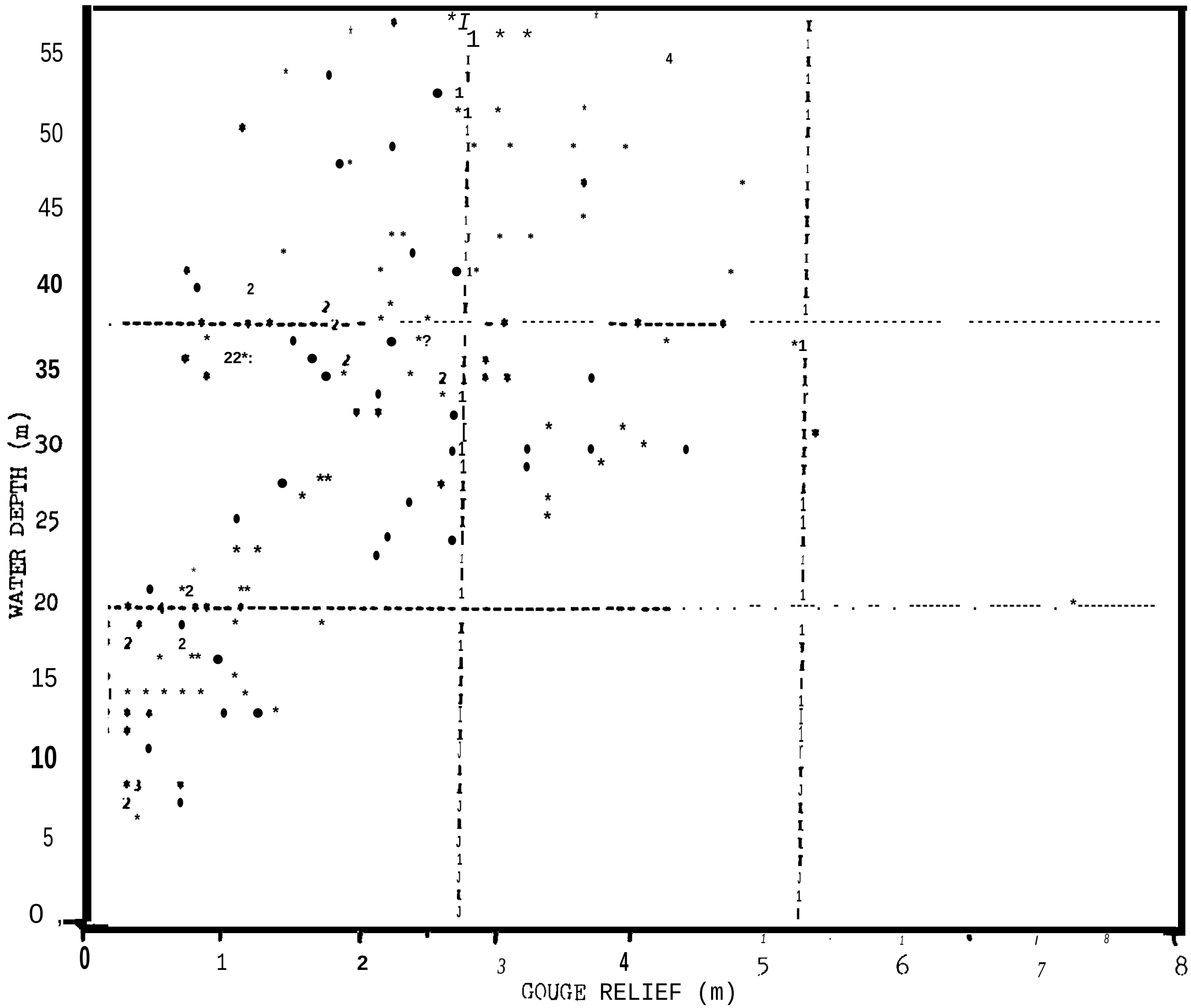

Figure 12. - Scattergram of gouge relief (ridge height plus incision depth) versus water depth.

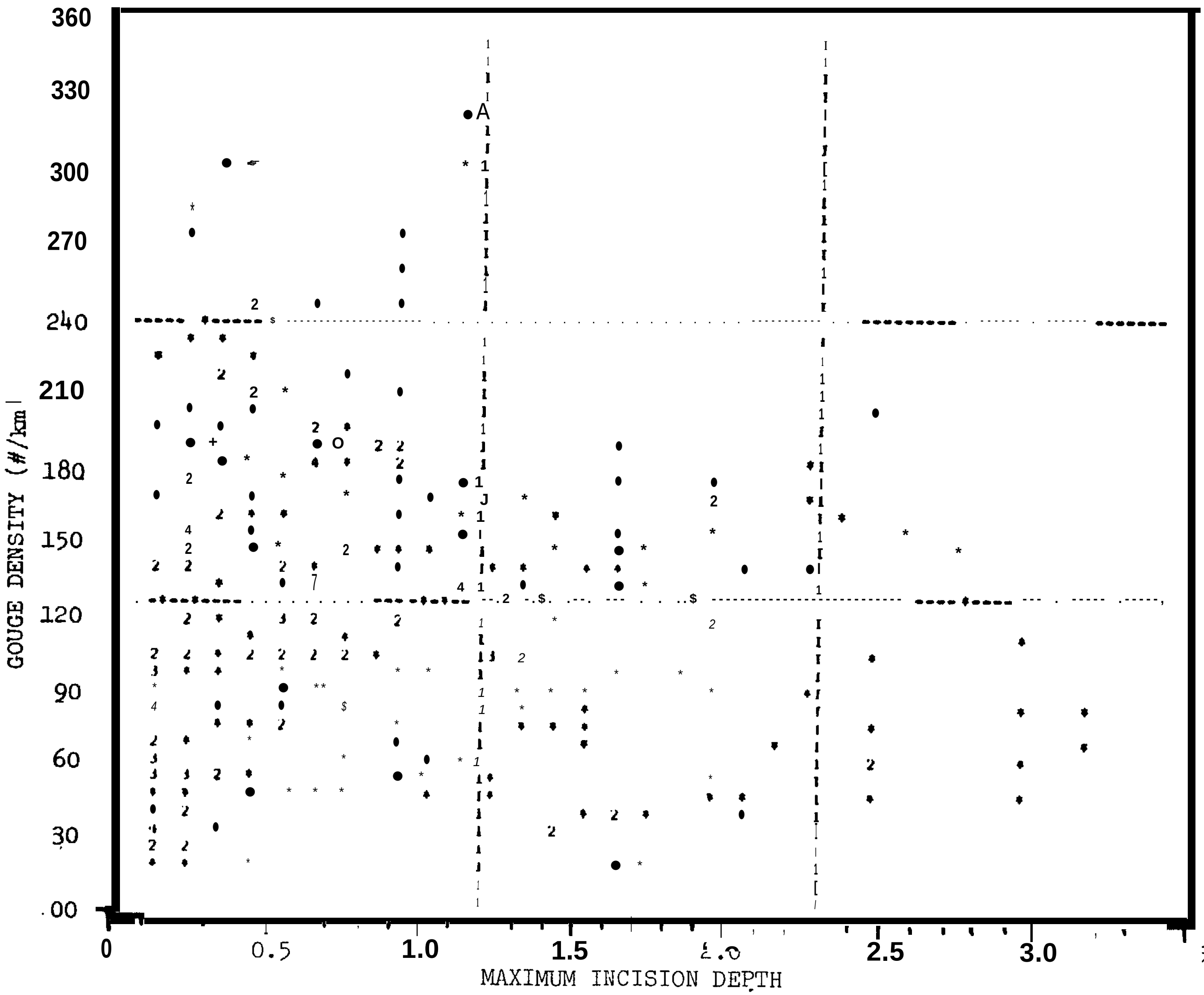

Figure 13. - Scattergram of maximum gouge incision depth versus gouge density.

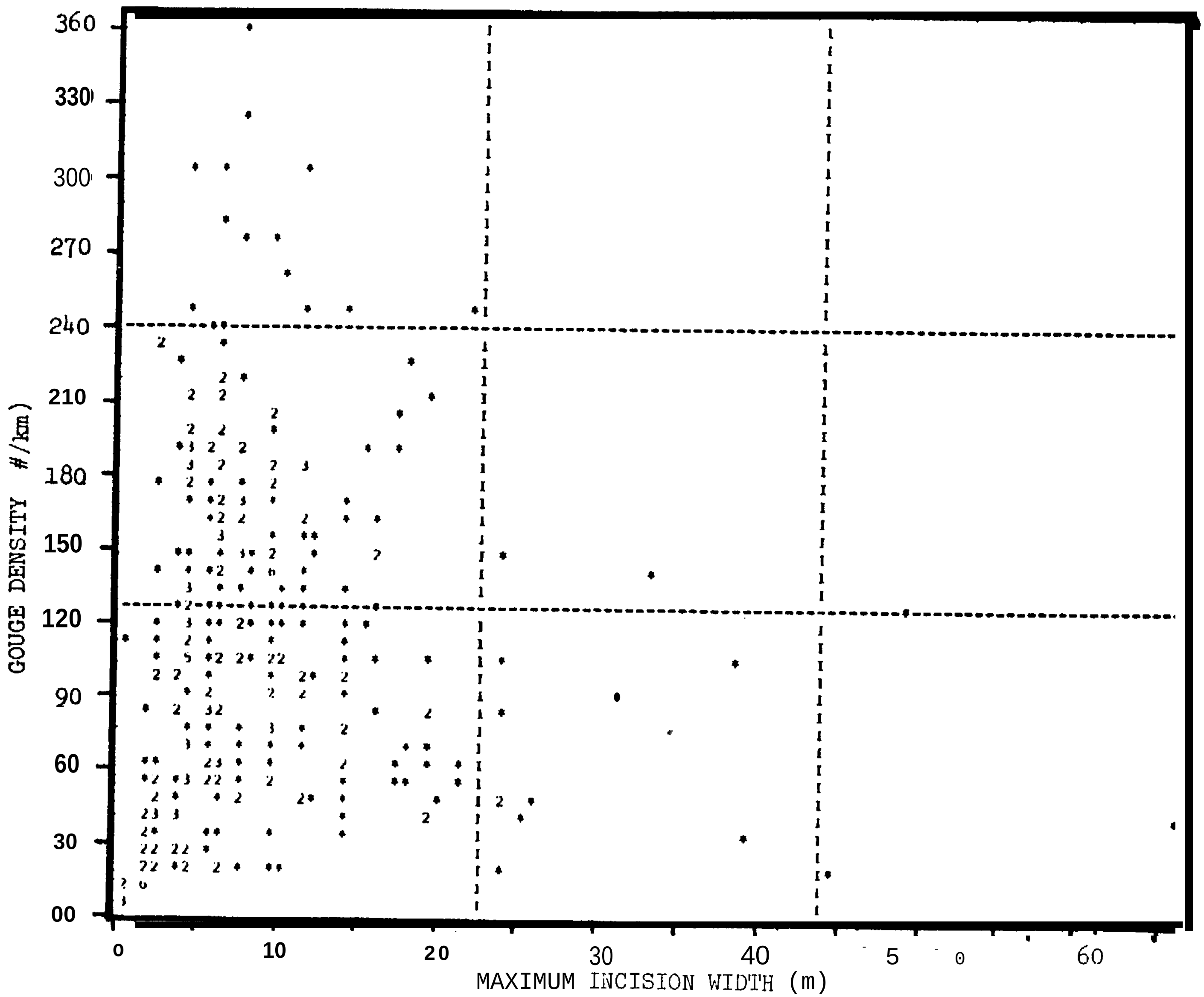

Figure 14. - Scattergram of maximum gouge incision width versus gouge density.

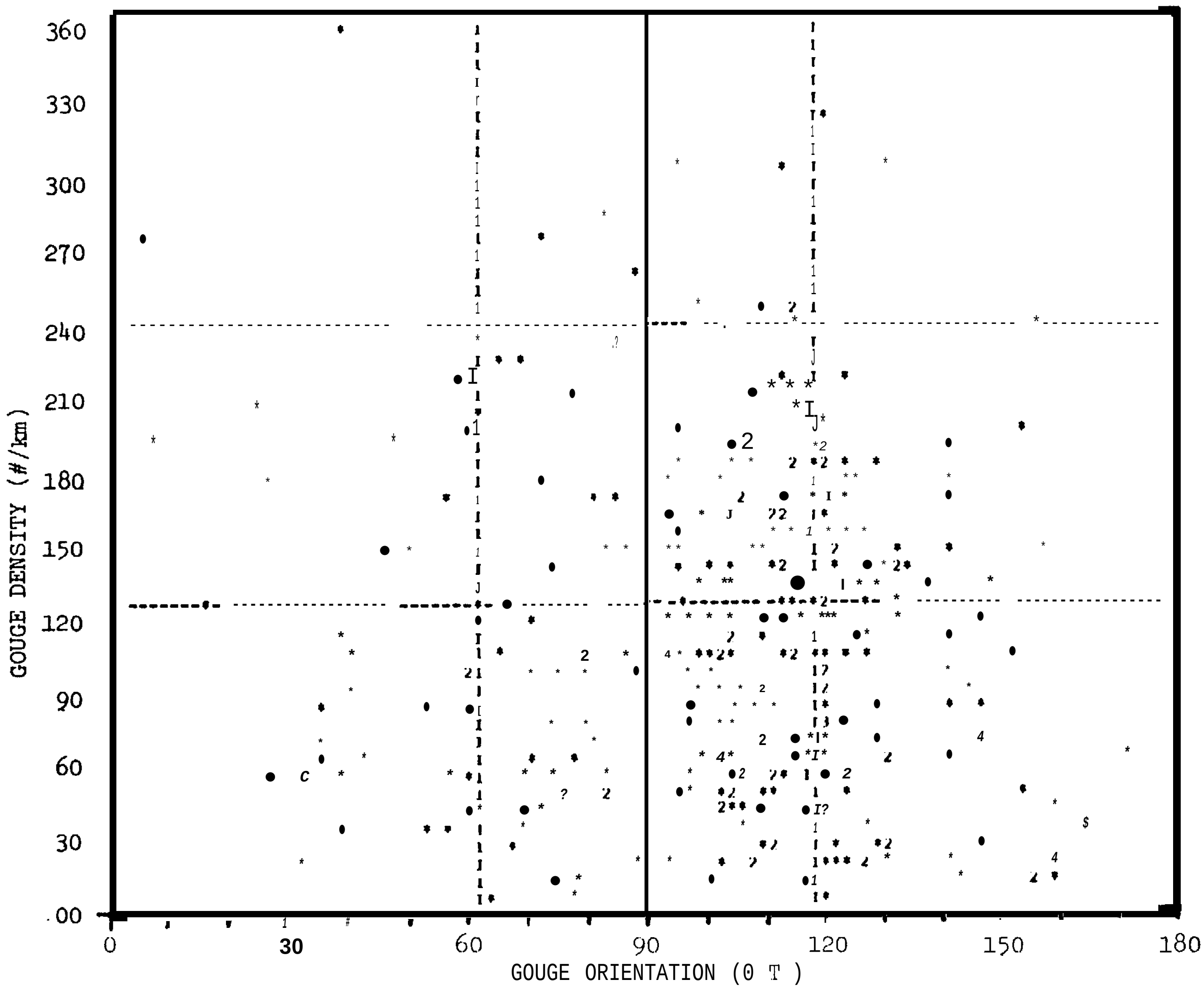

Figure 15. - **Scattergram of gouge orientation** versus gouge density.

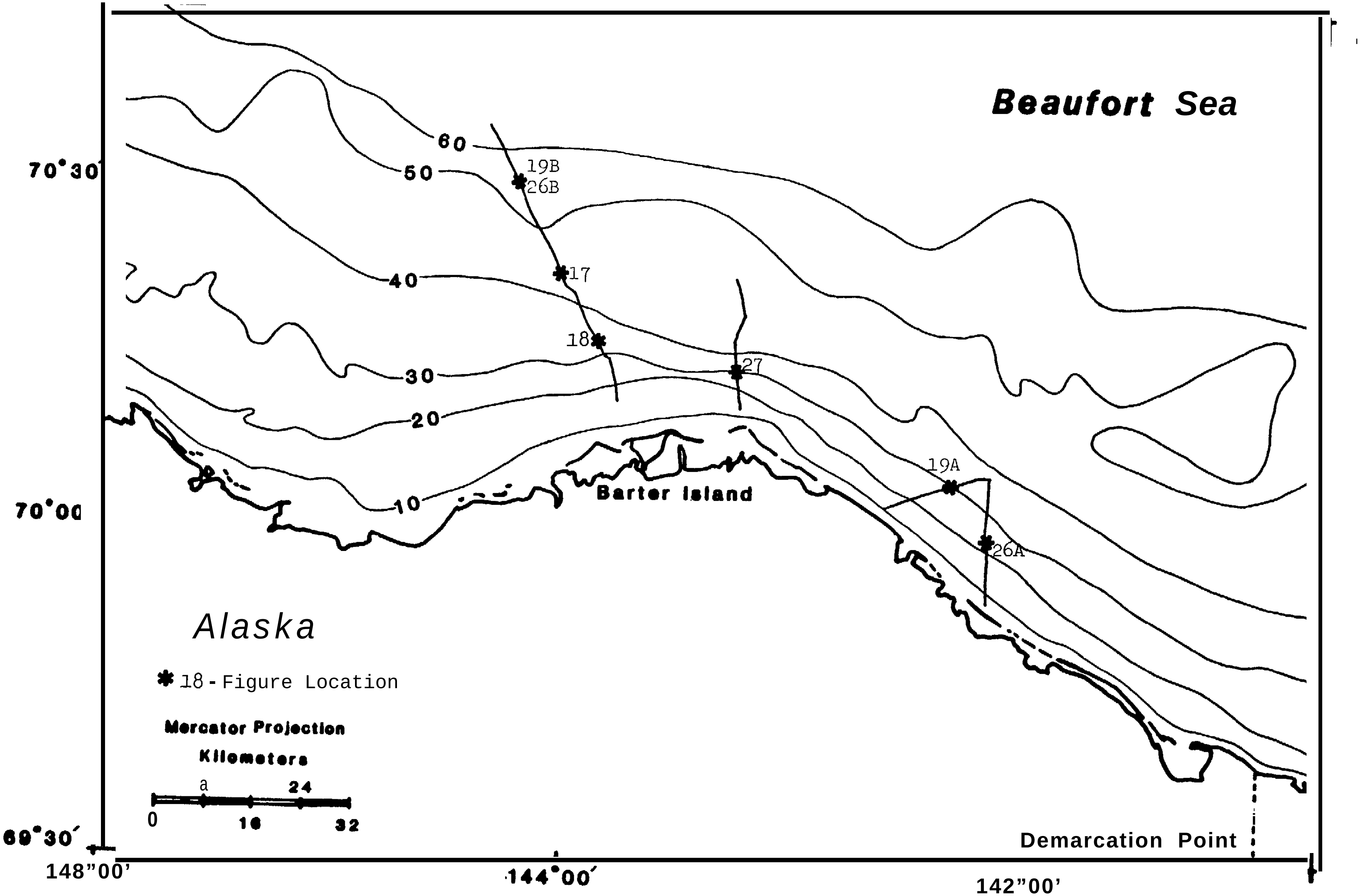

Figure **16.- Locations** for fathograms and monographs **shown** in **Figures** 17,18,19 A and B, 26 A and B, and 27. The **tracklines** from which these examples stem are also shown.

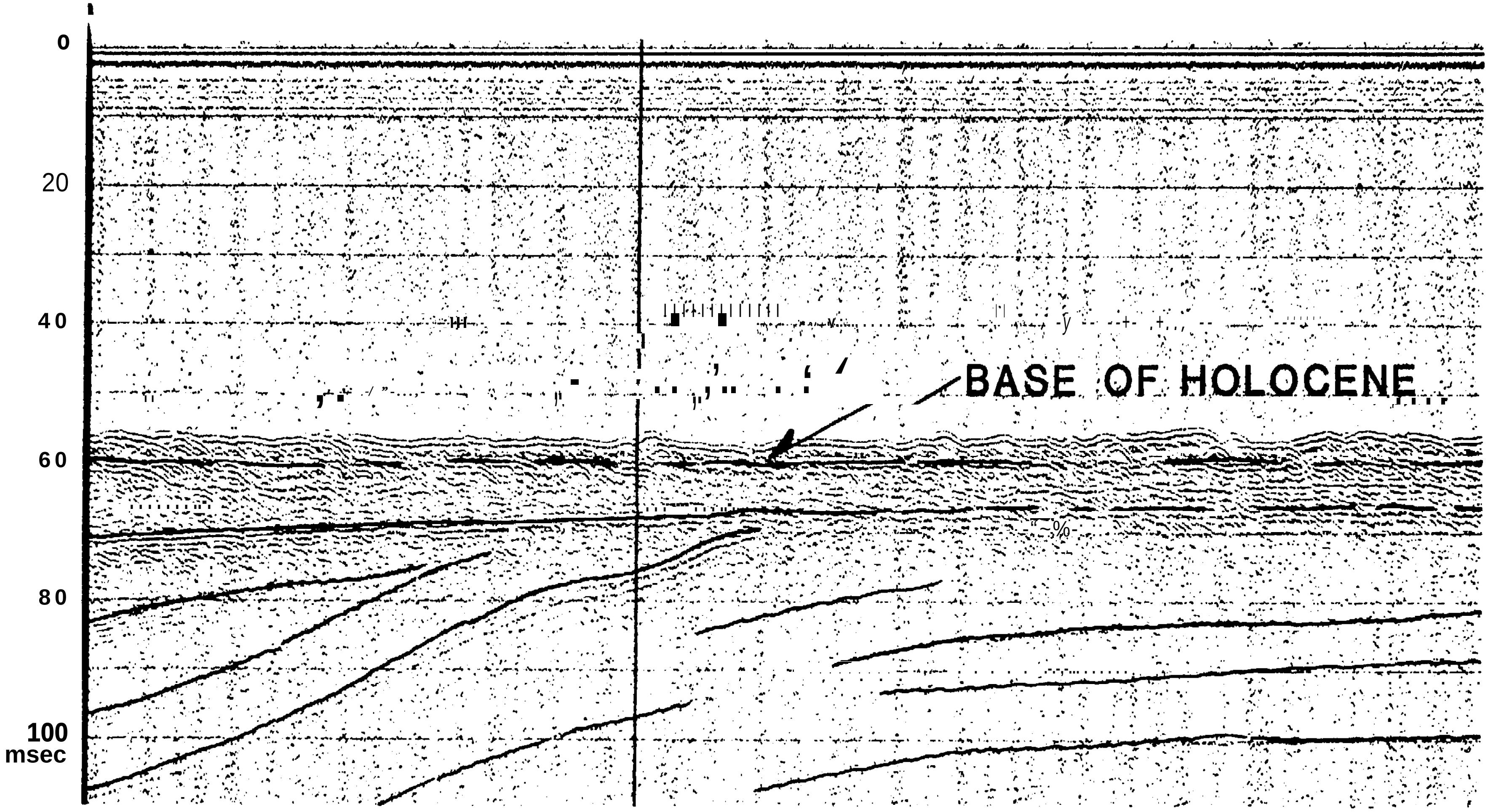

Figure 17. - High resolution **siesmic** record showing an angular unconformity below the base of the Holocene. Some of the reflectors have been highlighted for clarity.

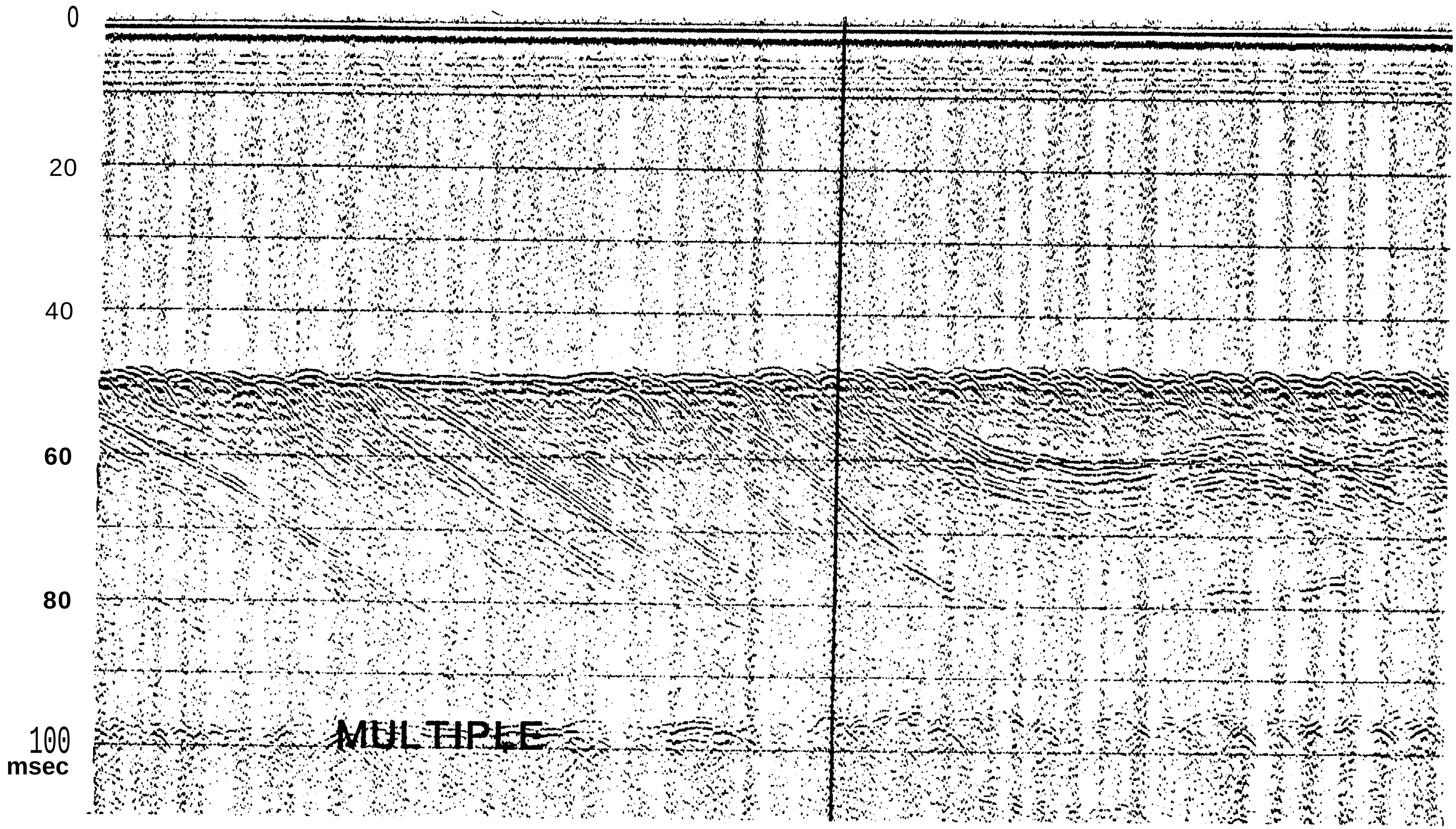

Figure 18. - High resolution seismic record showing dipping sediments truncated by the seafloor. The hyperbolas seen in the first 10 msec below the seafloor, and the rough seafloor relief, are the result of ice gouging.

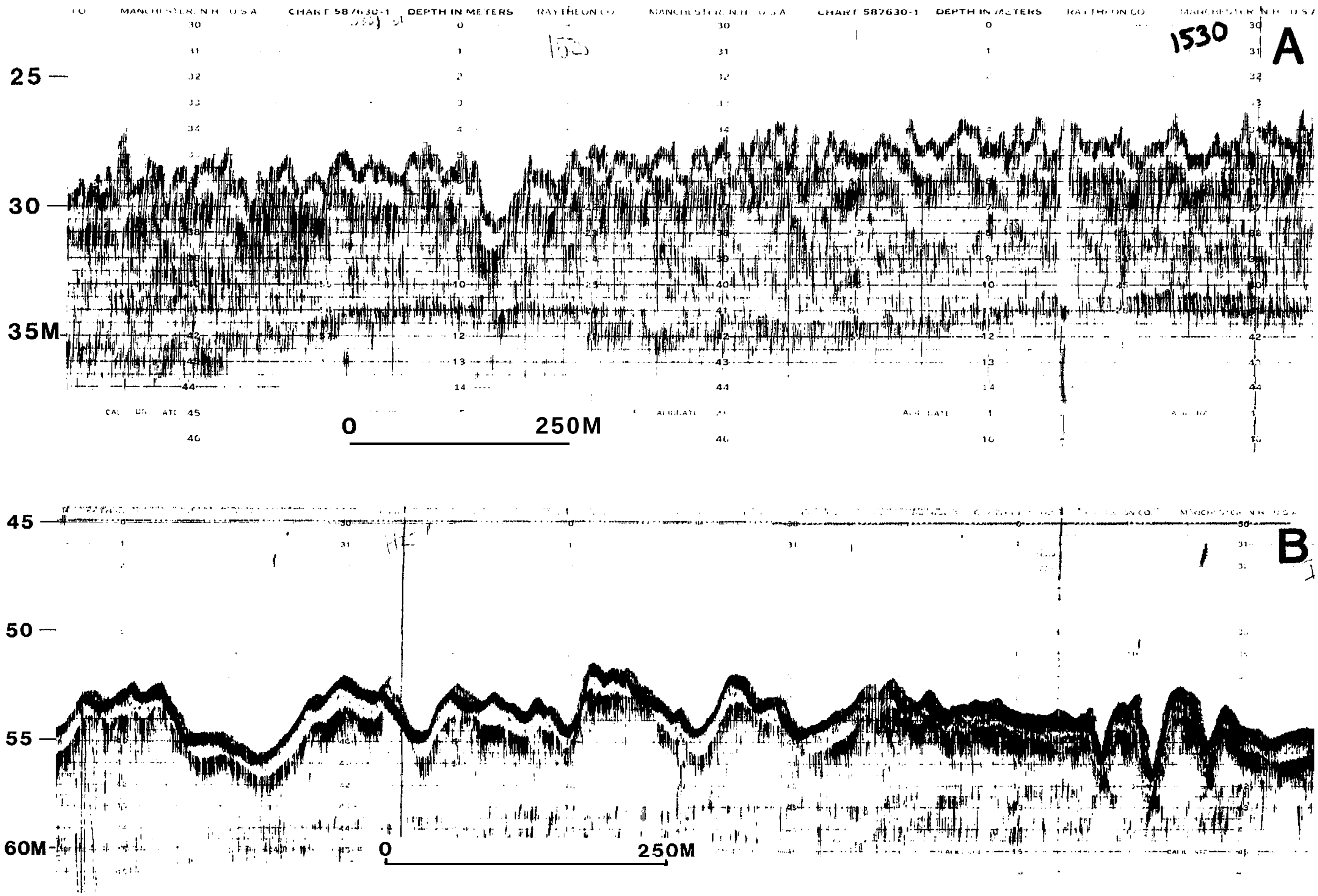

Figure 19. - Fathograms showing the extremes in bottom character: (A) rough relief and (B) smooth relief, which we interpret as cohesive and non-cohesive sediments, respectively. An undulating sub-bottom reflector is visible at approximately 35m in fathogram A, and a faint, left-dipping sub-bottom reflector is visible at approximately 60 m in fathogram B. Fathogram B covers the same section of trackline as sonograph B in Fig.26. (See Figures 16 and 26.)

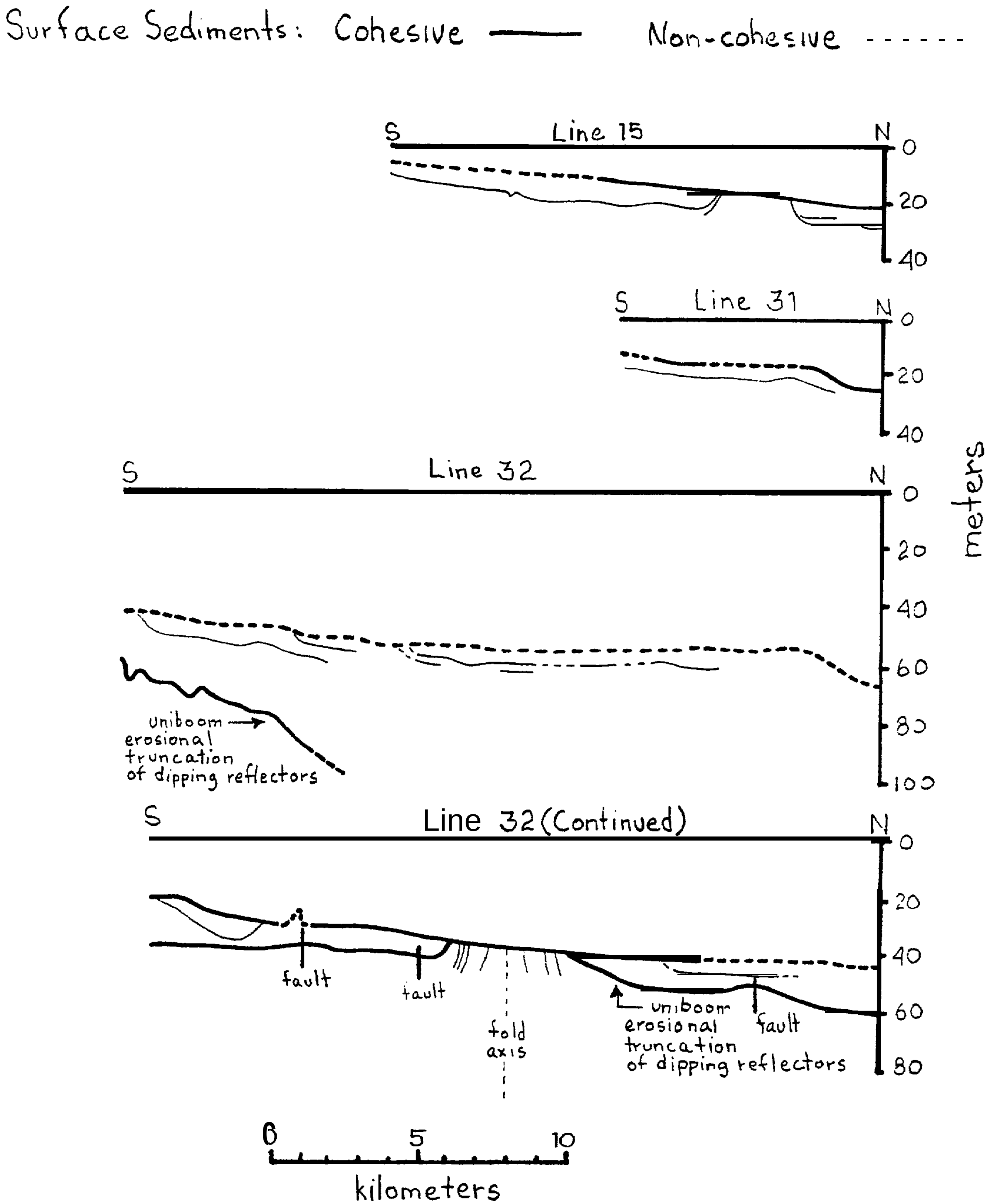

Figure 20. - Line drawings of 7kHz and **Uniboom** sub-bottom reflectors from **tracklines** between Camden **Bay** and Barter Island. Surface sediment textures in Figures 20 thru 23 are interpreted from sonargraphs and fathograms.

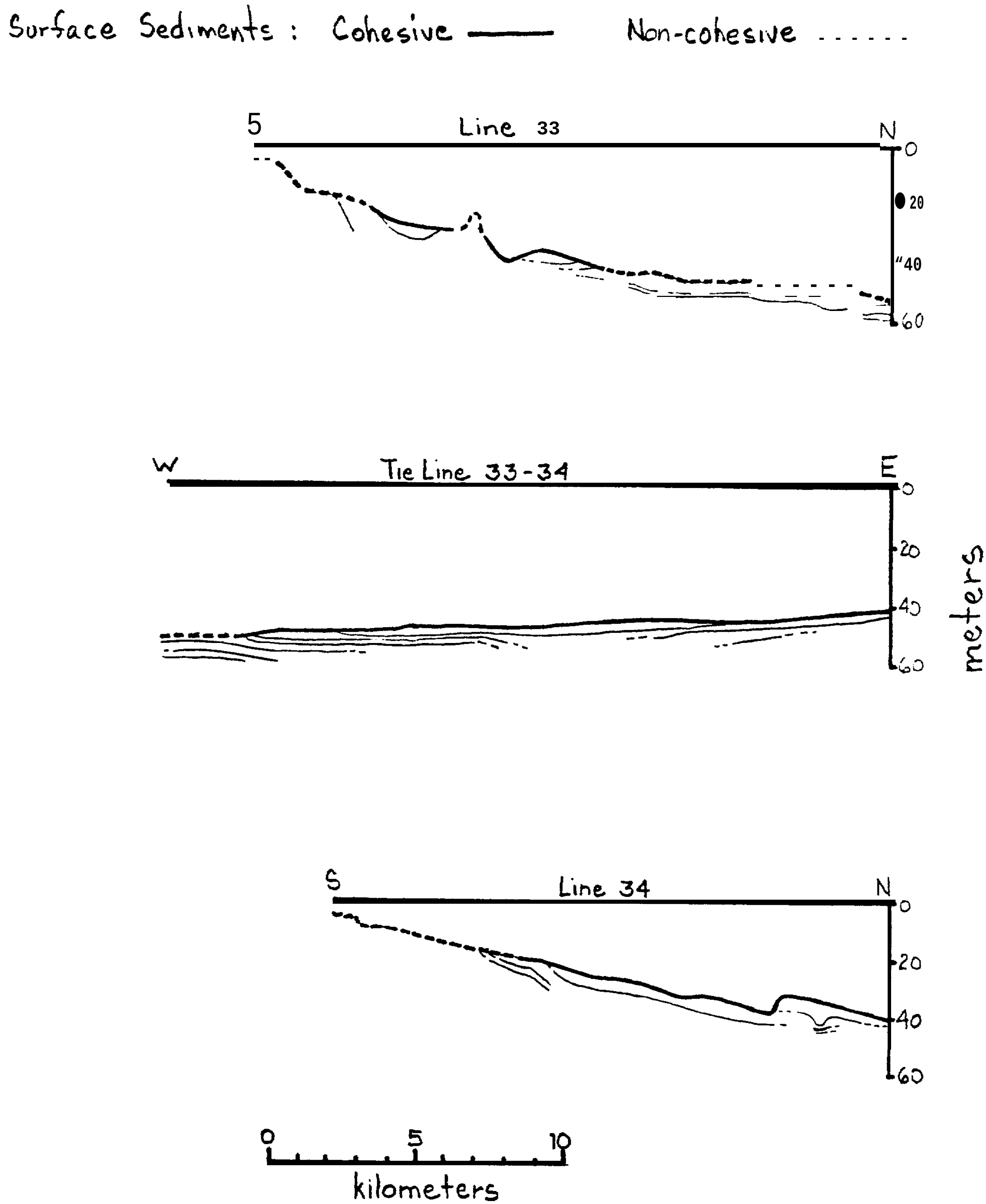

Figure 21.- Line drawings of 7kHz sub-bottom reflectors from tracklines between Barter Island and the Jago River.

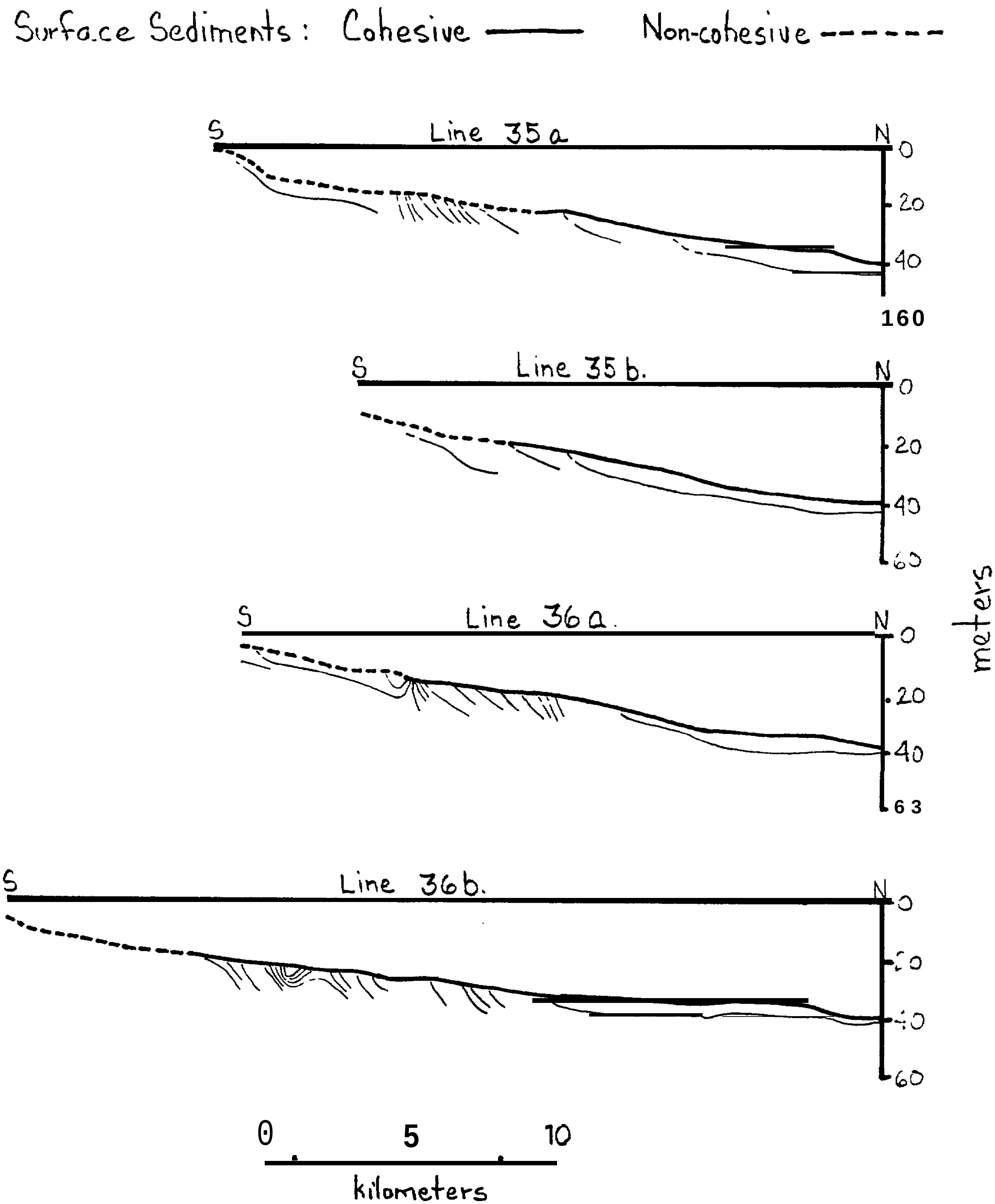

Figure 22. - Line drawings of 7kHz sub-bottom reflectors from track lines between the Jago River and Beaufort Lagoon.

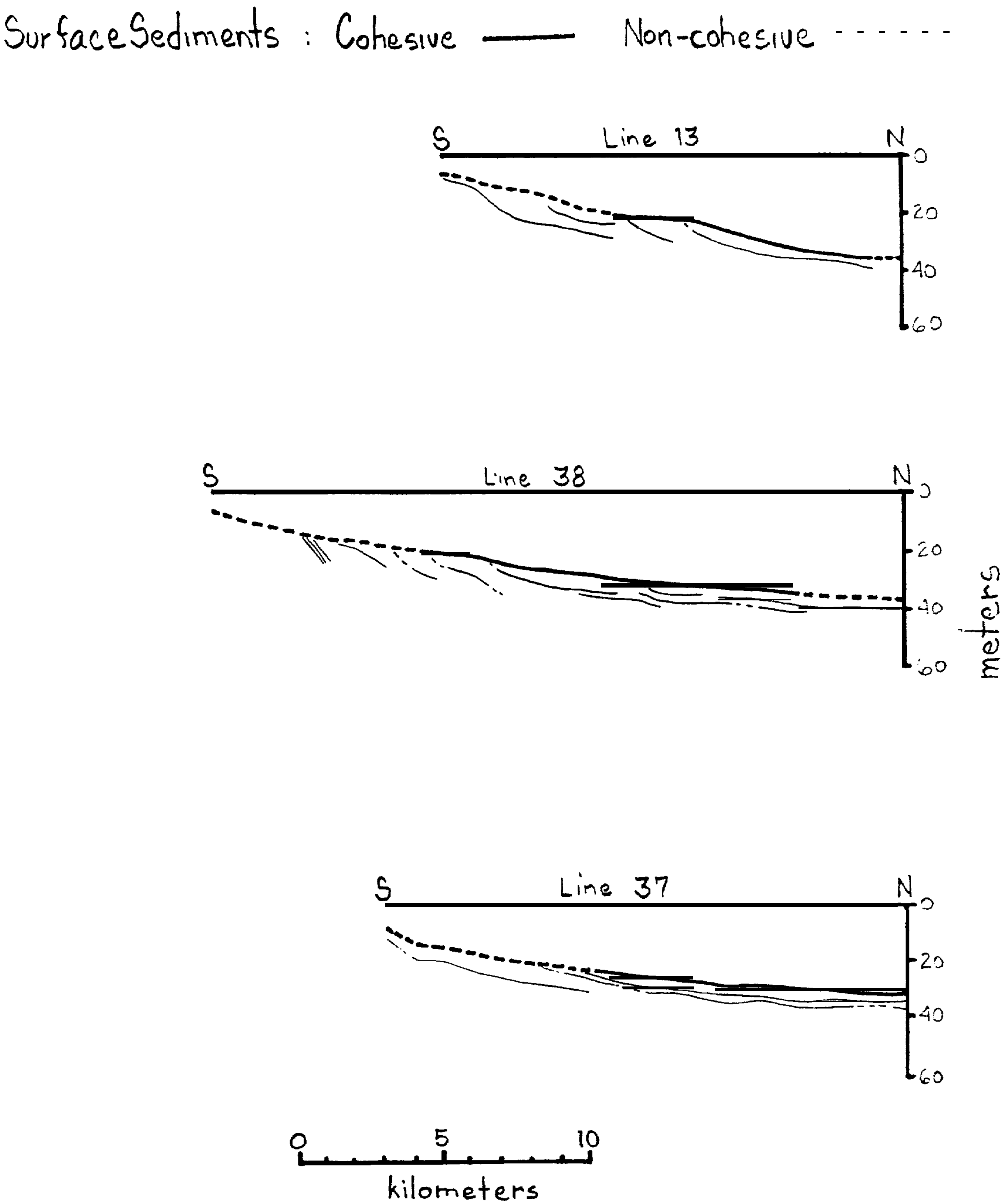

Figure 23. - Line drawings of 7kHz sub-bottom reflectors from **tracklines** between Beaufort Lagoon and Canadian border.

The seafloor trace also distinguishes between surface material types, as interpreted in the next section.

None of the sections traced in figures 20 through 23 contain reflector patterns revealing sediment accretion. On the contrary, most areas show shallow subbottom reflectors at varying angles to the sea floor, and cropping out somewhere along the traverse. We can detect no thickening of surface units towards rivers and coastal bluffs, the modern sediment sources. The tracings also do not reveal a thickening of units towards the shelf edge. Much more work will be necessary to gain an understanding of the stratigraphic complexities below the shelf surface. We prepared a scattergram with water depth plotted against sediment thickness above the first reflector (Fig. 24) and found that in the areas covered by our tracklines, the first reflector thickness is nowhere greater than 10 m and in most cases is less than 6 m.

Surficial Sediments - In our appraisal of surface sediment textures for the region from the Canning River to the Canadian border we used the surface sediment samples collected in 1981, the classification of geophysical records into cohesive and non-cohesive sediment types in l-km-track segments, and sediment analyses of samples reported by P. W. Barnes (1974).

The 1981 shipboard sample descriptions are condensed in table 2. Dots mark the sampling sites in figure 25 (station numbers are shown in Fig. 2). The comparison of the texture of surface sediment samples with the appearance of ice gouge relief on fathograms and monographs showed good correlation. Our interpretation of the geophysical records and the classification of relief forms into "rough" and "subdued," and classification of surface sediment textures into "cohesive" and "non-cohesive," is, of course, strongly influenced by detailed diving and sampling investigations made west of the Canning River. Figure 19 is a sample of fathograms recorded in areas of cohesive, muddy surface sediments (A) and non-cohesive, coarse, granular sediments (B). In the latter case the materials piled up in flanking ridges during the ice-gouging process move downslope to assume the angle of repose as the ice passes. Subsequently the aging process, aided by current effects on non-cohesive materials results in broadly rounded ice-gouge forms. The fine-grained surface sediments, on the other hand, assume relatively steep slopes, sometimes blocky shapes, during disruption by ice and remain in this position even through periods of current activity. The monographs shown in figure 26 represent samples of these two distinct bottom types. In figure 26A the gouges are cut into cohesive materials, most apparent in the ridge details. These are piles of jagged materials alined along gouges and lack the continuous smooth ridges seen in figure 26B. The smooth ridges of figure 26B were recorded at the same time and place as Fig. 19B. Figure 26A was chosen as an example because a first-year pressure ridge that produced the rake marks on the seafloor is firmly grounded at the end of the gouges.

The two bottom types interpreted from the geophysical records were plotted and the results are shown on the map in Figure 25. Coarse, granular materials blanket a strip from the coast to about 15-m water depth. Seaward of the 15-m water depth lies a zone of fine, cohesive surface sediments, which grade seaward into coarse granular materials. Coarse-grained materials can be traced uniformly for many kilometers on line 32, the long track extending northwestward from Barter Island to the shelf break. At 53-m depth we

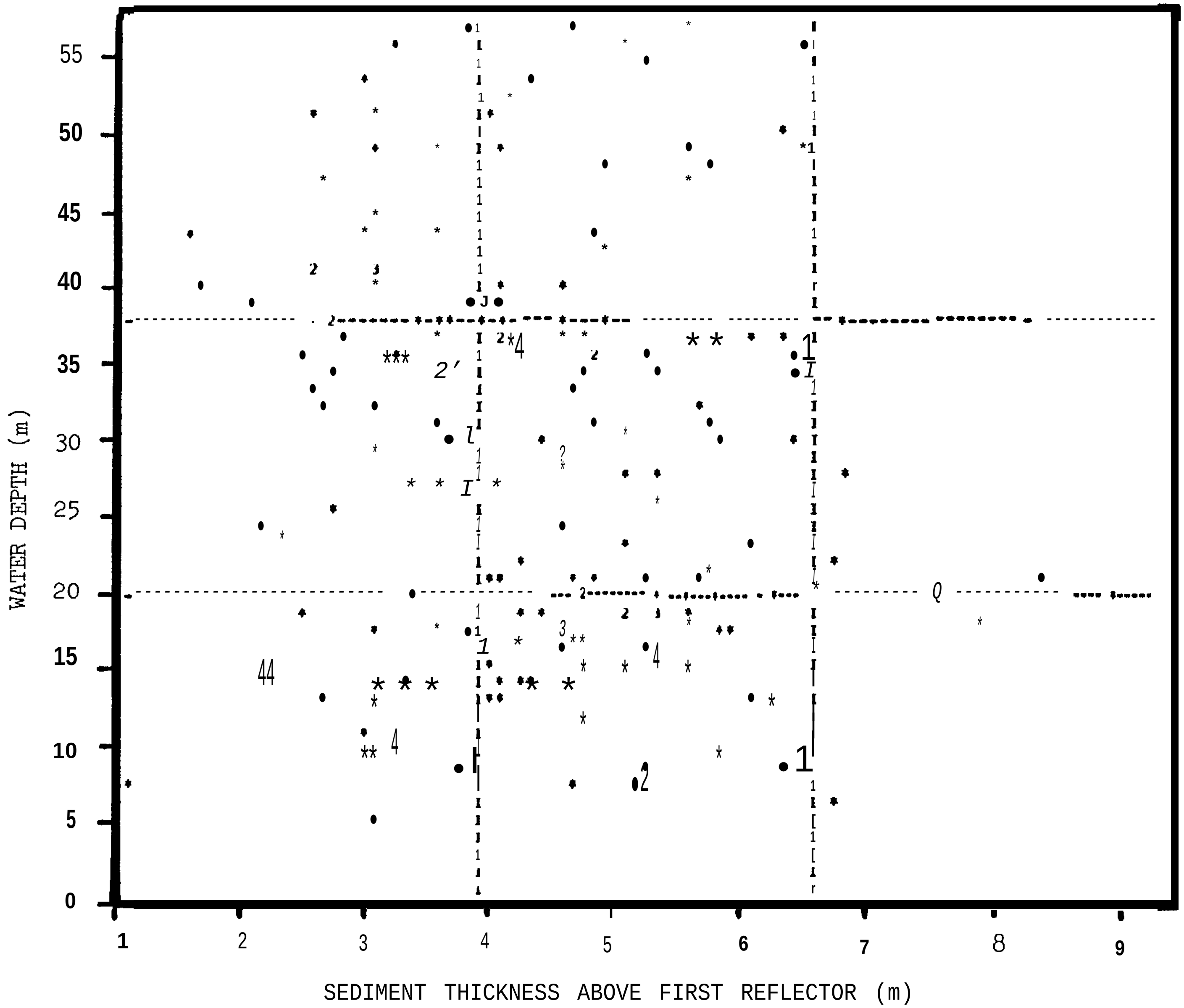

Figure 24. - **Scattergram** of sediment thickness above the first reflector versus water depth.

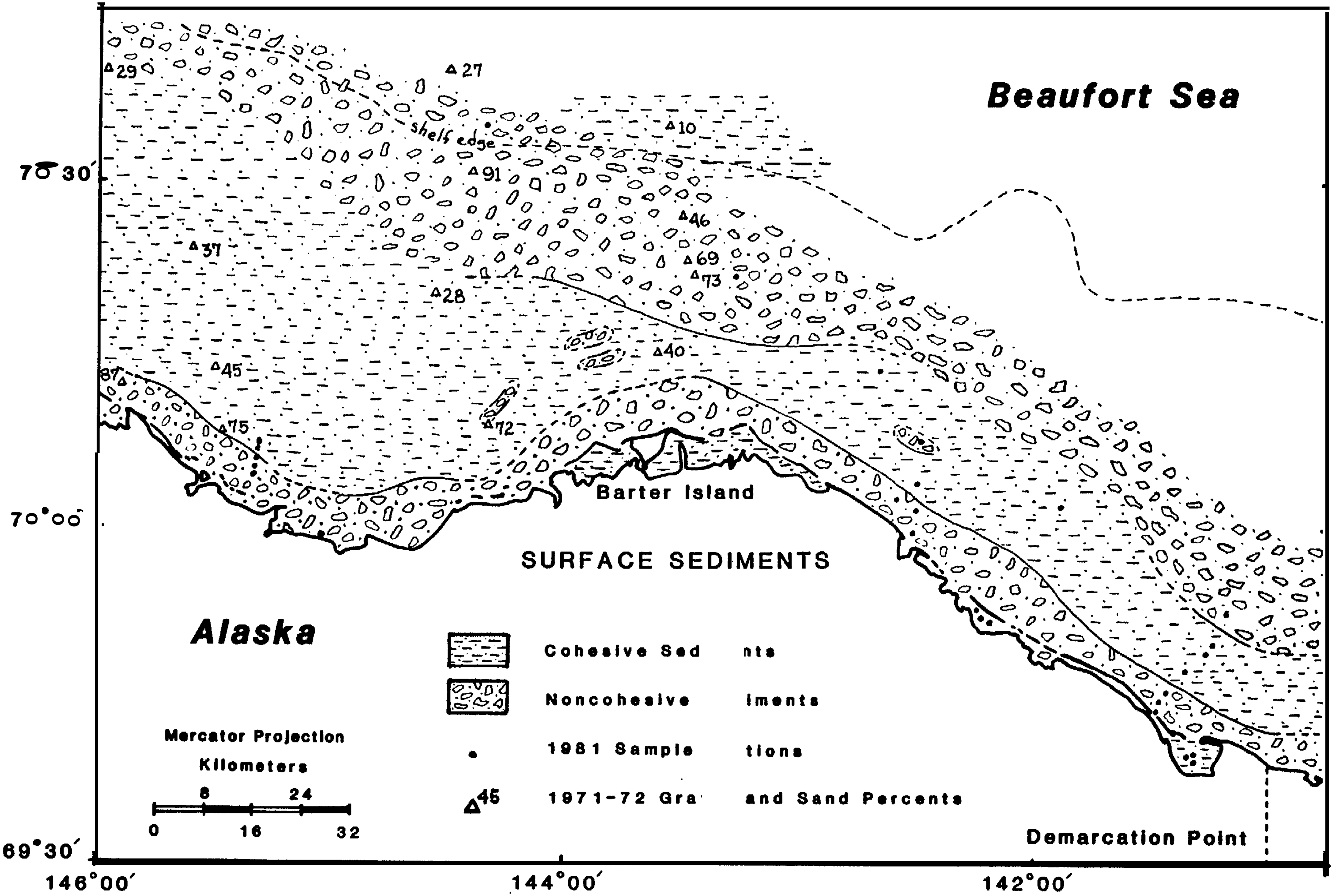

Figure 25.- Map of surface sediment textures, as interpreted from geophysical records and sediment samples. Percentages of combined sand and gravel are next to the old sample stations of Barnes (1974).

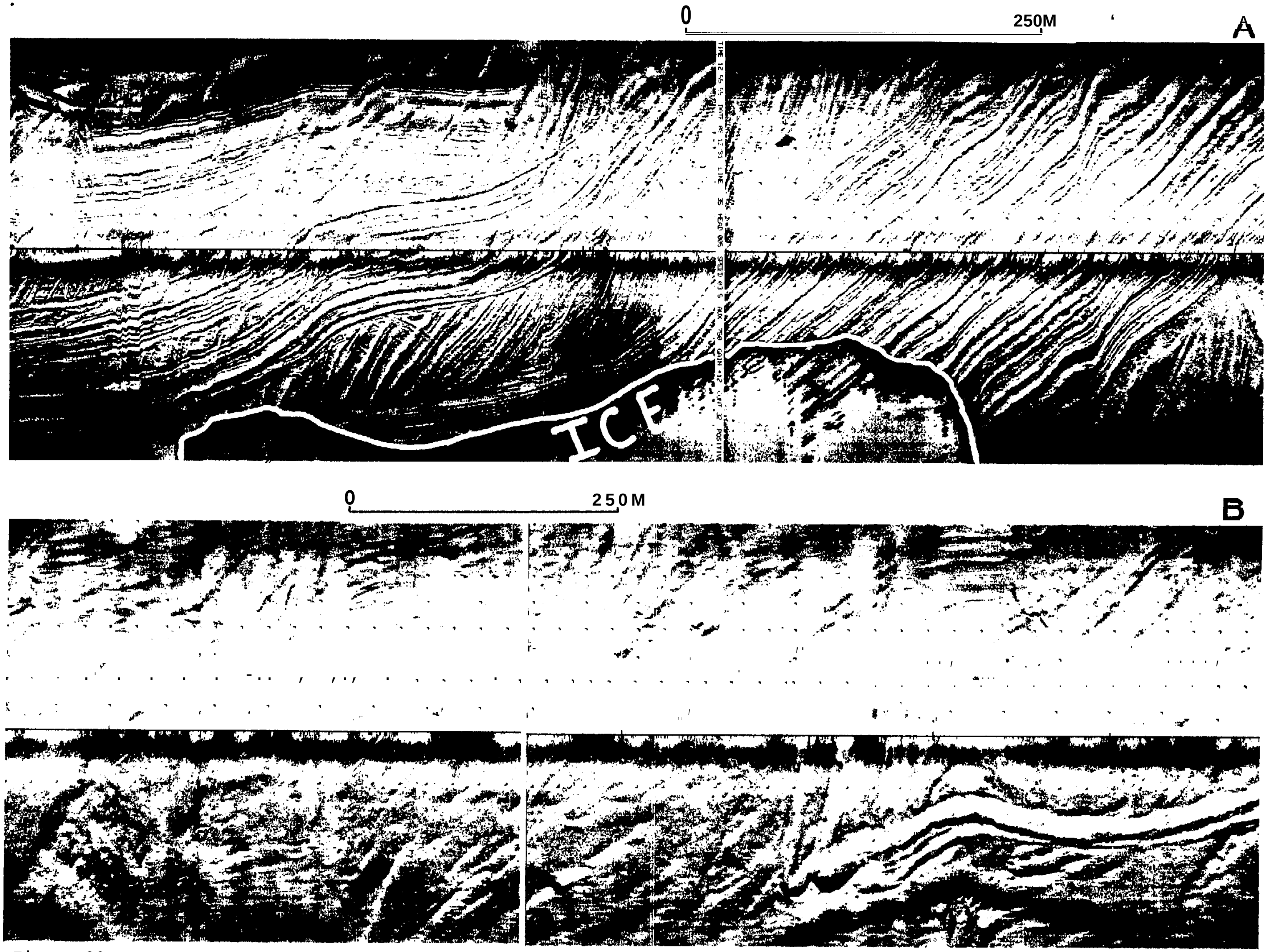

Figure 26. - Sonographs of rough (A) and smooth (B) gouge relief, a difference we interpret as due to the presence of cohesive (A) and non-cohesive (B) sediments. A large piece of ice is grounded in the lower center part of sonograph At gouges under the ice are hidden. Sonograph B corresponds to fathogram B in Fig. 19. The 3 sharp gouges on the fathogram are clearly visible on the sonograph. Even though there is a lot of relief in the area, the seafloor texture is smooth because of the non-cohesive nature of the sediments.

interrupted the line to collect a sample for verification and retrieved essentially clean gravel with attached organisms. The shoals within the strip of cohesive materials on the central shelf appear to be generally sand and grave 1. The numbers shown on the shelf west of Barter Island in figure 25 represent percentages of sand plus gravel taken from surface sediments analyzed by Barnes (1974). These values substantiate that much of the shelf surface, and especially the outer half, is covered with coarse granular materials.

Shoals of the stamukhi zone

The relationship of coastal promontories and shoals acting as strong points in the control of ice dynamics and zonation has been of considerable interest to our studies (Rearic and Barnes, 1980; Reimnitz et al. , 1978). The published charts for the study area do not show a pattern of shoals downdrift of the Barter Island promontory, similar to the pattern developed west of the Cross Island promontory. However our reconnaissance survey lines provide single crossings of a number of shoals. One long linear shoal off the Canning River was crudely defined by a number of crossings. A number of samples collected around that shoal show it to be composed of sand and gravel, similar to the shoals west of the Canning River which have been thoroughly studied. Most of the other shoals as well are composed of coarse granular materials as interpreted from the geophysical records. A sample crossing is shown in figure 27. The sonograph shows an intensely gouged sea floor on both sides of the shoal. Here the gouge flanks have the rough appearance typical of flanks associated with fine-grained cohesive materials. The shoal itself, is composed of coarse granular maerial with a smoothed, rounded surface and a trace of current ripples on the crest. Ice hangups are most common on such shoals and the sonograph shows such a stamukhi along the crest.

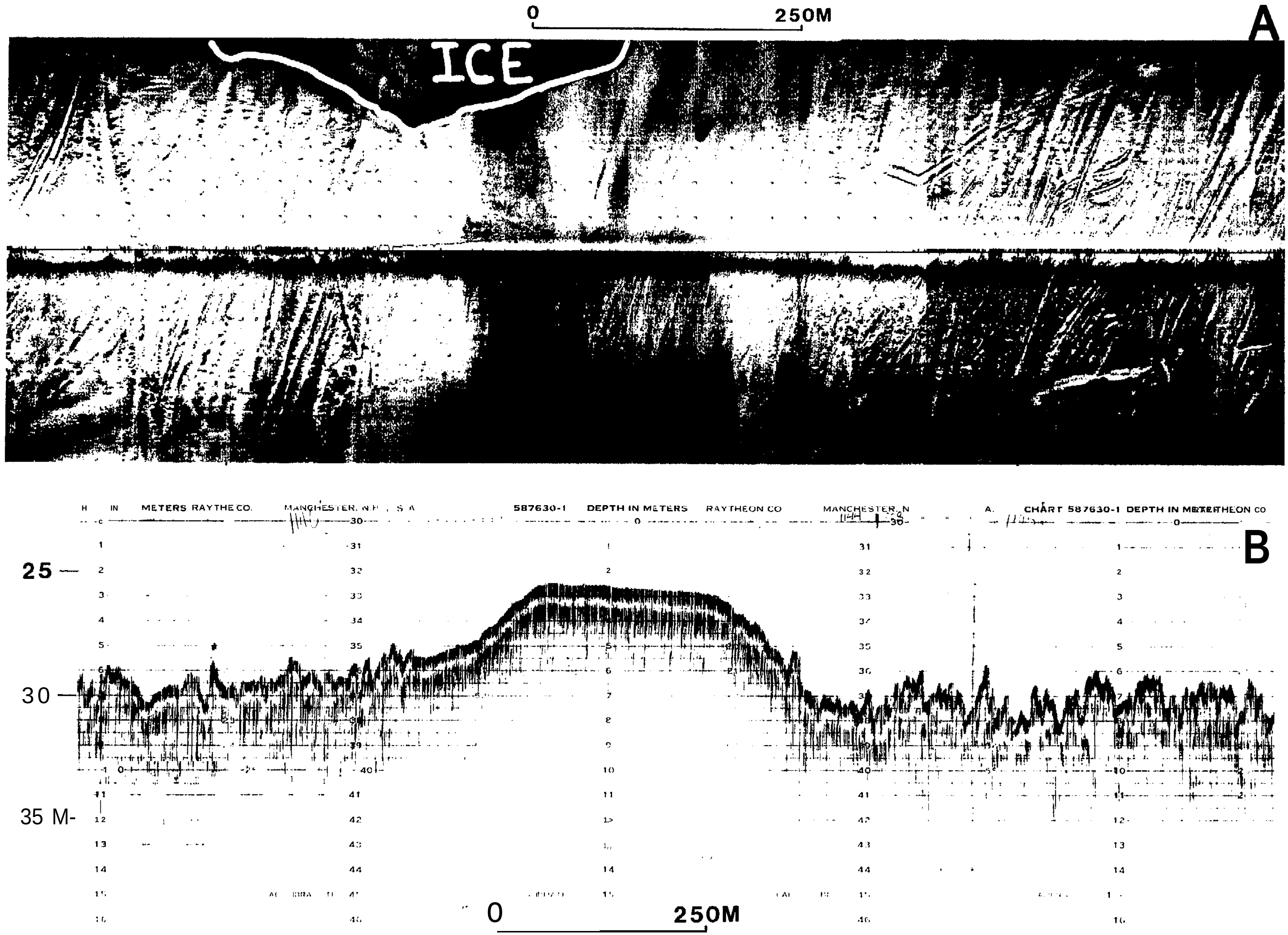

Figure 27. - **Sonograph** (A) and fathogram (B) of a shoal crossing in the **stamukhi** zone. The shoal crest is characterized by a smooth, noncohesive texture, while the surrounding bottom exemplifies the jagged, cohesive sediment texture. The smoothness of the shoal crest, which is gouged by ice more frequently than the surrounding bottom, indicates that hydraulic processes rapidly rework the sediments on the shoal crest.

DISCUSSION AND CONCLUSIONS

Sedimentation - From combined coring, diving, and seismic profiling studies in numerous different marine geological environments and settings west of the Canning River, we are convinced that where repeated ice plowing occurs with slow sediment accretion, no continuous sedimentary units develop. Sediments come to rest mainly in troughs of gouges, and the shape and extent of a trough define the limits of sedimentary units. Assuming that the depositional environment on the Beaufort Sea shelf has remained constant for the last 10,000 years or longer, with slow accretion and rapid re-gouging, we see no possibility for the blanket of Holocene sediment to contain continuous internal reflectors.

All indications are that modern sediment accumulations, possibly present in lagoons and bays, are essentially lacking on the open shelf. The fine grained, cohesive sediment mapped in a band on the central shelf, may be modern deposits of several meters thickness, and most likely the shoals of the stamukhi zone are constructional features post-dating the last transgression. The coarse granular materials on the inner shelf and on the outer shelf seem to be relict deposits. The relict nature of the shelf edge gravels has been discussed by Barnes and Reimnitz (1974), Naidu and Mowatt (1974), and Rodeick (1975). Their interpretations are based on a) low rates of modern ice rafting of coarse clasts compared to overall sediment accretion rate, b) observed ferromanganese coatings on cobbles, c) about 15,000 year old C^{14} ages for near-surface shelf edge and upper slope sediments, d) source rock considerations, and e) lack of seaward decrease in sediment grain size from coarse grained near the sediment source to fine grained near the outer edge of the shelf.

Grantz and Dinter (1980) mapped a seaward thickening wedge of Holocene silt and clay on the Beaufort Sea shelf, using high resolution seismic reflection records. In the Barter Island area in particular, they show a large area of structurally formed and truncated stratified deposits lacking any Holocene marine sediments, and flanked on the northeast- and northwest side by Holocene marine sediments thickening to 30 and 40 m at the shelf edge. Line #32 of the present study was aimed at reaching the shelf edge where modern marine sediments are 40 m thick, where sedimentation rates presumably are high, and where the greatest water depth at which ice gouges exist would correspond with the present maximum ice keel depth to be encountered within the Beaufort Gyre. We reasoned that rapid sediment accretion suggested by 40 m of modern sediment would eliminate gouges within a period of several hundred years. Line #32 (for cross section see figure 20) does indeed cross the erosional region on the mid shelf, where older sediments are truncated by the seafloor, but it does not show a thick homogeneous wedge of Holocene sediments to seaward. The character of the gouges recorded, in fact, made us suspect gravelly surface sediments and we interrupted the line to collect a sample. The gravel retrieved at 52 m water depth, along with the homogeneous appearance of the records for tens of kilometers, supports previous sedimentological interpretations that much of the outer shelf in the eastern Alaskan Beaufort Sea is blanketed by relict gravels, and not by Holocene marine sediments.

One of the major potential modern sediment sources for the eastern Alaska

Beaufort Sea shelf is the Mackenzie River. Therefore, a comparison with the sediment distribution on the shelf between our study area and the Mackenzie Delta will shed additional light on our belief that the outer shelf off northern Alaska is a surface of non-deposition. Figure 28 is a compilation of our sediment texture map extending to the Canadian border, and a map of sand-plus-gravel percentages for the region east of the border by Vilks et al. (1979). The Canadian shelf surface is covered by sand and gravel. Yorath et al. (1970) interpreted the sandy gravels, sands, and hard pebbly lutites as "relict glacial deposits and and ice-pressed tills." Thus, these combined interpretations of shelf surface sediments, while not matching across the border in detail, leave no room for a thick wedge of Holocene silt and clay on the outer shelf. Our interpretation of the 1981 seismic data also rules out the possibility of thick Holocene sediments in our study area. A thorough study of this problem is urgent because the interpretation that slumping, sliding, and faulting are active geohazards in this area (Grantz and Dinter, 1980) is strongly dependent on whether the shelf edge sediments are old or recent.

Ice Gouging - The statistical mean values calculated for various ice gouge parameters in the present study area are greater than those of the area west of the Canning River (Barnes et al., 1982). This canbe explainedby the exclusion of surveys in lagoons and bays from our present data analysis. Aside of this difference, the overall patterns are found extending all the way to the Canadian border and probably beyond. Along the entire Alaskan shelf, the 18 m isobath separates inshore low density and size values from offshore high density and size values. The stamukhi zone, lying between 18 and 36 meters of water depth, in all areas stands out by having the highest values on most parameters measured, but east of the Canning River the values do not decrease offshore with the same consistency as to the west of the Canning River. Gouge densities follow the most consistent pattern along the entire shelf. In the present study area, the pattern of highest gouge densities corresponds rather well with a 5-year composite of ice-ridges prepared by Stringer (1978) and shown in figure 29. The significance of the 13 m isobath as a boundary between areas of mild and severe ice hazards (Kovacs, 1980) has not shown up in our data analysis for the length of the shelf.

The trends of water depth contours in the present study area are more northerly on the average than those west of the Canning River, and a comparison of ice gouge trends in the two regions supports previous conclusions that the plowing action aligns with the isobaths. In this study we were again able to demonstrate the tendency for ice gouges to align more consistently isobath-parallel on the up-drift (eastern) side of major promontories, and more variably on the down-drift side (Barnes, et. al. , 1982).

The lack of gouges on the crests of shoals in the stamukhi zone, and the presence of hydraulic bedforms in coarse granular materials, again supports our contention that active hydraulic processes reshape, and perhaps help to rebuild, features that should soon be eliminated by ice scouring. Even in the consistent presence of stamukhi (grounded floes) on the shoals during surveys (figure 27) we rarely detect gouges, while the surrounding low and more protected terrain with cohesive surface sediments is highly gouged.

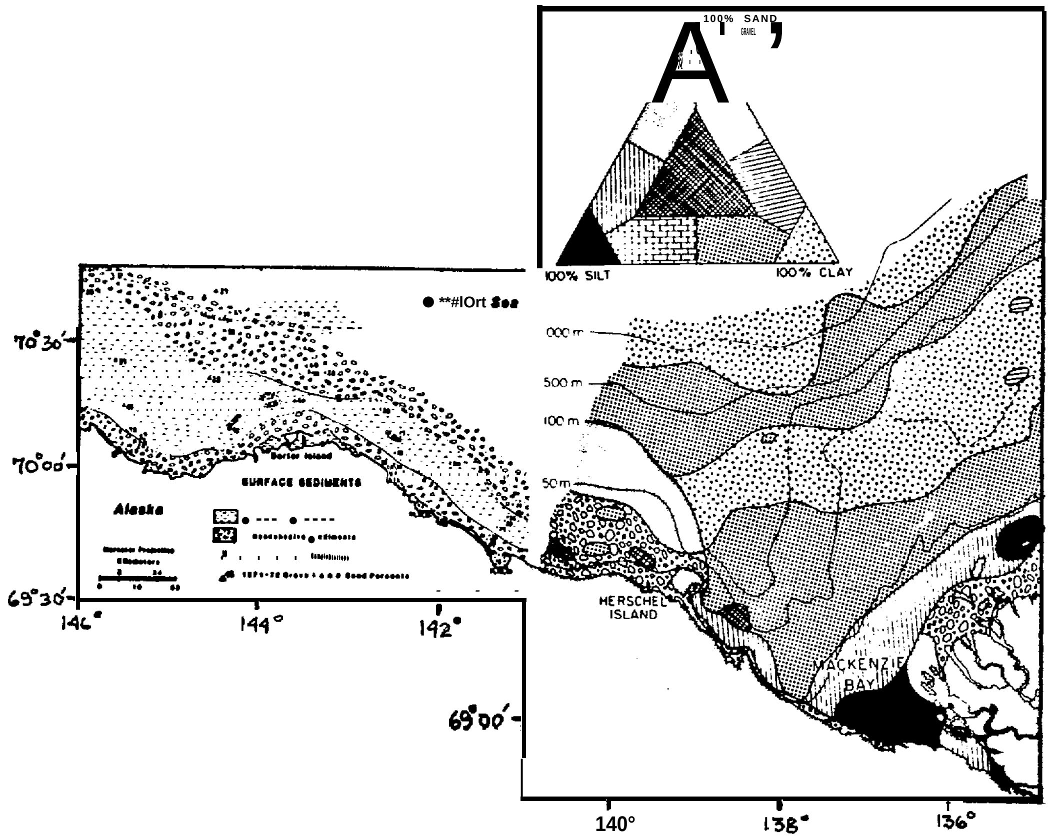

Figure 28. - Composite of surface sediment textures from the present study, and east the Canadian border
(Vilks et al. , 1979).

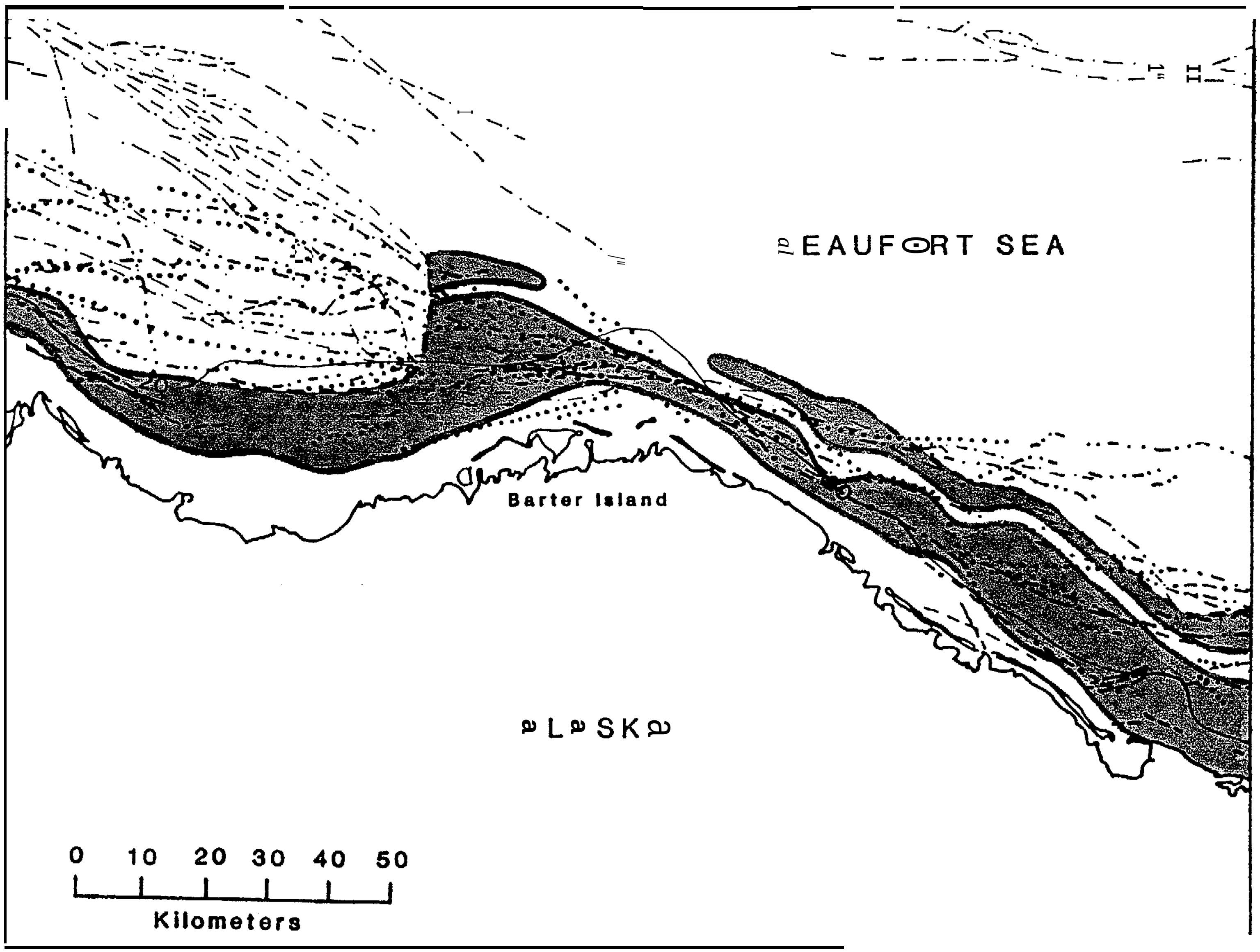

Figure 29.- A composite of ice ridges in the Barter Island area from 1973 to 1977, from Stringer et al., 1978. The shaded area indicates zones of high density gouging (> 100 gouges per km) that were contoured from data of the present study (see figure 6).

The total vertical relief possible for a single gouge was previously estimated (Barnes, et al., 1982) by adding the highest ridge from one gouge to the deepest trough of another. In the recent surveys we found 8 meters total relief across a single gouge, leading us to believe that accurate estimates of ice gouge extremes can now be made from our large volume of data.

Drifting ice scraping the seafloor appears to be an efficient planation agent, producing erosional unconformities and truncating thick sets of dipping strata. We feel that hydraulic processes alone acting on that same surface would have sculptured it in accordance with the resistance to erosion offered by the different geologic units. Relatively well indurated beds would form scarps. The ice pack acting on an extensive, non-homogenous surface, however, seems to take the different lithologic units down to the same level by focusing mainly on the high points. Viewed in this light, the existence of major, well defined shoals, is more perplexing.

So far we have been unable to relate the intensity of ice gouging to the underlying geology. Thus, one could also argue that all geologic strata exposed to the action of ice in the study area are weak compared to the forces of the moving ice keels.

New Evidence for greater than expected ice depth - Favorable ice conditions in 1981, and a relatively mrrow shelf east of the Canning River enabled the R/V KARLUK to survey ice gouges in generally greater water depth than has been possible in the western sector. One particular line was extended to the very shelf edge. In general, the relationship between ice gouging and water depth in the study area is similar to that determined for areas west of the Canning River, with lowest values for certain gouge parameters inshore and offshore of the stamukhi zone. In the presenty study, ice gouges were traced to maximum water depth of 58 meters. Beyond that we saw only very broad, subdued relief features unrelated to ice keel interaction. Among the bedforms beyond the deepwater gouge limits we found slope-parallel, rhythmic lineations of 3 m wave length but less than 20 cm of relief, which we interpret as probable hydraulic bedforms. These indicators, along with the presence of surface gravels rather than fine materials, the sub-clued nature of gouge relief forms, the seaward decrease in ridge height relative to trough depth and width, and especially the recorded current pulses of up to 50 cm per second along the shelf edge (Aagard, 1977) all suggest that active currents rework the deep water gouges. Based on these considerations, the gouges found at 58 m water depth are modern rather than relict (produced during lower stands of sea level). Surficial hyperbolic reflections on Uniboom crossings of the shelf edge between Barrow and the Canadian border, and the accompanying surface roughness, are fairly certain indicators for the presence of ice gouges. These indicators can be traced in 28 representative traverses to maximum water depths of between 60 and 64 meters (Dave Dinter, U.S. Geological Survey, oral communications, 1982).

Our previous contention that ice gouges seen on the Beaufort Sea shelf at depths greater than 47 m (the deepest keel actually observed) are modern has recently found additional support. Marine geologic studies by Canadian workers in the Southern Beaufort Sea no longer call for lower sea levels to account for the deepest gouges observed. Also, statistical treatment of ice keel distributions in Arctic deep water, allow for 60 m deep keels to occur at a rate of one every few hundred years (Peter Wadhams, oral communication, 1982). These findings are of little consequence at the present stage of petroleum development in the Alaskan Beaufort Sea, but may in the future assume considerable importance.

Shallow seismic stratigraphy - Our analysis of seismic records has not progressed to the stage where correlating individual units from line to line, and their interpretation, can be attempted. However, we can put some limits on the surface units - the Holocene marine sediments. Our reasoning leading to the conclusion that Holocene marine sediments cannot contain continuous seismic reflectors has been presented above. This is not only a theory, it has been proven true in numerous site specific studies in the west. Based on this fact, the sediment thicknesses above the first sub-bottom reflector are the upper limit for the thickness of Holocene marine sediments. A plot of these values (Fig. 24) against water depth shows no trend. The mean depth below the sea floor is nearly 7 meters. But as discussed before, the geometry of units defined by the shallow reflectors, excludes them in most regions from being Holocene marine sediments. They are in fact older units.

Thick sections of stratified, tectonically deformed, probably Pleistocene strata dipping at various angles, are truncated by the seafloor over extensive regions in the Barter Island area. We have not been able to trace any portions of the section to Barter Island from the Flaxman Island area, where well known stratigraphy exists from boreholes. Some faults extend to near the sea floor, but we are unable to detect surface scarps or other signs of recent fault displacements. However, the smooth truncation surface, extending for many kilometers cutting across numerous strata of presumably different erodability, suggests that ice scouring is an efficient planation agent that treats all mateials available uniformly. Thus, the lack of modern fault scarps in our data is not necessarily evidence against recent movement postulatedby Grantz and Dinter (1980).

Sand and Gravel Resources - Triggered in part by the high demand for sand and gravel as construction material for offshore petroleum development, the Federal Government is making preparations for managing these resources on the Arctic shelf through a leasing program. In the present study area all indications are that gravel is plentiful, even in deep water, and need not be hauled great distances. In areas were active gouging creates up to 8 m of vertical relief, the seafloor reflectivity and overall appearance is homogeneous for many kilometers. If such areas on the outer shelf were underlain by interbedded mud, sand and gravel, the plowed ridges would reveal such inhomogeneities. The sea floor would be littered with slabs of stiff silty clay. The appearance of the geophysical records suggests to us that on the outer shelf fairly clean, coarse granular materials have a thickness of at least several meters. However, several box cores from the outer shelf contain firm mud units (Barnes and Reimnitz, 1974), raising questions that need answers.

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APPENDIX

to

ATTACHMENT "I"

T = transitional S = smooth R = Rough C = cohesive N = non-cohesive DMP

Line Number : 08 Year : 1981

gouge measurements in meters

	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density C D	Orientation (°T)	Sediment Cohesion	REMARKS
000	24.3	—	.4	.4	17	168/161	105 / 285	R/C	.4 Km of sonar missing. Count adjusted. SSS Range 150 m
001	22.8	—	.8	.9	—	—	—	R/C	no sonar for this segment.
002	22.1	27.1	.8	.6	—	—	—	R/C	no sonar for this segment.
003	21.3	25.5	.4	.5	—	—	—	R/C	no Sonar for this Segment
004	17.4	22.7	<.2	<.2	—	—	—	S/N	no sonar for this segment. 4 Meter bench at start of segment (includes 1 meter shoal on crest).
005	17.0	22.0	.2	.3	3	97/93	080/260	S/N	.4 Km of sonar missing. Count adjusted.
006	16.1	20.6	<.2	<.2	11	88/127	156/246	S/N	1 multi-gouge - 12 inc., 78 m, 144°T
007	17.3	22.3	<.2	<.2	5	70/112	20/110	S/N	gouge orientations are highly variable.
008	18.0	23.5	<.2	.2	5	87/106	36/126	S/N	" " " " "
009	18.8	24.3	.2	.2	4	142/221	158/248	R/C	Orientation is highly variable. 3 Multi-Gouges - 24 incs. in largest - 125 m wide - 240°T
010	19.1	24.4	.4	.3	8	152/219	24/114	R/C	
011	19.6	25.3	.4	.5	7	175/231	151/241	R/C	orientation is highly variable.
012	20.1	25.3	.5	.7	5	169/243	26/116	R/C	Orientation is highly variable. large multi gouge with 13 incisions and oriented 90°T. width = 65 m.
013	20.2	25.8	.4	.5	5	124/119	70/250	R/C	sonar quality poor - many range changes.
014	18.1	24.5	.4	.5	16	156/190	143/323	R/C	orientation is highly variable.
015	16.9	22.8	.3	.5	5	121/174	26/206	R/C	600 m of sonar missing. count adjusted.
016	15.9	21.4	<.2	<.2	5	39/48	126/306	S/N	4 meter shoal in middle of segment. most gouging ends on offshore slope of the shoal.
017	12.7	18.2	<.2	<.2	4	25/46	166/256	S/N	
018	13.0	—	.2	.2	10	42/51	35/125	S/N	
019	15.8	—	.2	.3	7	137/167	145/235	T	orientation is highly variable.
020	16.4	—	.2	.3	5	149/197	150/240	R/C	orientation is highly variable.
021	17.0	—	.4	.9	—	—	—	R/C	no sonar this segment
022	16.9	—	.3	.6	6	167/240	23/113	R/C	orientation is highly variable.
023	17.8	—	.5	.5	5	148/213	23/113	R/C	orientation is highly variable.
024	17.5	22.8	.9	.9	18	172/187	136/226	R/C	orientation is highly variable.
025	18.2	24.9	.6	.6	7	136/148	45/225	R/C	orientation is variable.
026	17.2	22.5	.7	.5	—	—	—	R/C	no sonar this segment.
027	16.4	20.9	.4	.4	4	85/83	120/300	T	400 M of sonar missing. Count adjusted.
028	13.7	19.0	.2	<.2	3	16/17	128/308	S/N	3.5 M. shoal in middle of segment

Line Number : 08 | Year : 1981 | gouge measurements in meters

SEGMENT	Fathogram Measurements: Water Depth (meters)	Fathogram Measurements: Reflector "A"	Fathogram Measurements: Gouge Depth	Fathogram Measurements: Ridge Height	Sonograph Measurements: Gouge Width	Sonograph Measurements: Density	Sonograph Measurements: Orientation (°T)	Sonograph Measurements: Sediment Cohesion	REMARKS
029	10.3	15.0	<.2	<.2	2	25/26	131/311	S/N	a series of shoals (4-5) with gouging on crest & sand waves in troughs (λ=~1m θ=147°T)
030	10.6	—	<.2	<.2	3	21/26	147/327	S/N	
031	9.0	—	<.2	<.2	2	6/7	137/157	S/N	
032	10.2	—	<.2	<.2	2	72/83	40/60	S/N	large multi-gouge (pressure ridge type?) 58 incisions, 205 m wide, θ = 60°T
033	11.9	15.2	.2	<.2	6	57/56	83/103	S/N	
034	12.3	18.3	.3	.8	7	47/49	49/69	T	3 meter shoal at beginning of segment. Heavier gouging at seaward base.
035	15.8	20.5	.2	.5	5	113/123	43/63	R/C	Orientation is highly variable.
036	17.2	21.7							

Line Number: [illegible] Year: 1981 gouge measurements in meters

SEGMENT	Water Depth (meters)	Reflector "A" M	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T) M	Sediment Cohesion	REMARKS
000	4.1	—	—	—	—	—	—	—	no sonar this segment. Range 150m
001	6.1	—	—	—	—	—	—	—	no sonar this segment.
002	7.5	—	—	—	—	—	—	—	no sonar this segment.
003	8.0	—	.2	.2	6	57/56	121/221	N ?	Sonar Range: 150 m
004	8.1	—	.5	<.2	6	51/49	117/217	N ?	
005	8.0	13.2	.3	.2	5	54/52	110/210	N ?	Secondary orientation: 130°T
006	7.7	13.5	.2	.2	6	85/82	115/215	N ?	30 cm hole noted on both BATS AND SONAR. Other holes noted on sonar. (7 meter diameter)
007	7.2	13.5	<.2	<.2	—	—	—	—	no sonar this segment.
008	6.9	11.5	<.2	<.2	3	67/96	153/253	N	250 m of sonar missing. Count adjusted.
009	6.5	11.7	.2	.2	2	26/28	133/233	N	30 cm hole noter on BATS & SONAR.
010	6.0	12.7	.2	.3	3	28/31	45/55	N	
011	6.2	11.3	.2	.2	2	37/38	51/61	N	
012	6.8	12.0	.3	.5	3	34/35	50/60	N	SMOOTH SUBBOTTOM DIPS UNDER AN UPPER REFLECTOR (ROUGH) THAT SURFACES AT KM. 12. *
013	7.3	11.0	.3	.5	4	37/36	59/69	N	SUBBOTTOM IS very rough.
014	8.2	11.1	.2	.3	7	[illegible]	[illegible]	[illegible]	SUBBOTTOM IS VERY rough (gouge like appearance)
015	9.1	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	ROUGH SUBBOTTOM
016	9.5	12.4	.3	.3	4	17/16	78/88	N	ROUGH -------
017	10.5	13.5	<.2	.2	2	10/10	63/73	N	ROUGH SUBBOTTOM. 200 m of sonar missing. count adjusted.
018	11.5	14.5	<.2	.3	3	36/35	62/72	N	ROUGH SUBBOTTOM. 100 m sonar missing. count adjusted.
019	12.3	15.1	<.2	.2	5	74/118	21/96	N ?	ROUGH SUB.
020	12.7	14.8	<.2	.5	3	81/107	30/105	T ?	ROUGH SUB.
021	12.8	15.0	.6	.7	20	171/209	34/109	R/C	Gouge character change. Pressure Ridge gouging at end of segment. Many larger gouges.
022	13.0	—	.5	.8	19	110/233	169/244	R/C	Secondary orientation: 85°T
023	13.0	17.7	<.2	.3	8	100/160	19/94	R/C	Gouging becoming less intense.
024	12.9	17.2	.3	.2	7	133/282	8/83	R/C	SUBBOTTOM BECOMES FLAT AGAIN.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	R/C	multi-gouge - 13 incisions, 95 m wide, 86°T
026	12.7	16.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	R/C	
027	12.5	16.4	<.2	<.2	4	103/182	15/90	R/C	
028	12.3	[illegible]	[illegible]	—	7	[illegible]	[illegible]	RC	no fathogram for segment. PRESSURE RIDGE TYPE GOUGING.

Line Number : 09					Year : 1981				gouge measurements in meters
	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density C D	Orientation (°T)	Sediment Cohesion	REMARKS
029	12.1	16.5	.3	.3	10	75/137.	15/90	R/C	
030	11.9	16.5	.5	1.0	17	69/146	8/83	R/C	
031	12.2	16.2	.5	.9	3	108/104	113/113	R/C	
032	13.3	16.6	.2	.8	7	105/103	60/80	R/C	
033	14.0	17.9	.5	.7	8	171/168	61/81	R/C	very high gouge density but gouges are small and shallow.
034	14.8	20.0	.5	.6	5	217/213	58/78	R/C	gouges are narrow (~1-2m wide)
035	15.4	19.9	.3	.7	8	263/274	52/72	R/C	400m of sonar missing. Count adjusted
036	15.8	20.4	.3	.6	3	165/172	52/72	R/C	high density gouging stops at middle of segment for no apparent reason (no shoals, etc.).
037	16.1	19.9	<.2	.3	7	58/59	57/77	R/C ?	
038	16.5	22.3	<.2	.2	3	50/61.	153/173	R/C ?	(Because they are shallow they may be covered by a transitory layer ??)
039	17.2	—	<.2	.2	7	56/58	51/71	R/C ?	
040	17.9	22.1	.3	.5	—	—	—	—	NO SONAR THIS SEGMENT. HIGH DENSITY GOUGING STARTS AGAIN AT SEG. START (NO APPARENT REASON).
041	19.0	23.5	.3	.7	8	226/362	18/38	R/C	2 SUBBOTTOM REFLECTORS - TOP ONE APPEARS TO SURFACE AT ~ 40 Km point. *
042	19.7	24.3	.3	.3	5	140/141	53/73	S/N ?	long low shoal with little gouging on it. Probably sand and will not hold gouges. 500M Sonar missing-adj.
043	19.0	—	.4	.6	7	214/216	123/238	R/C	high density gouging starts again after shoal crossing.
044	20.0	24.0	.3	.5	10	198/200	126/241	R/C	END OF SONAR
045	18.5	23.0	.3	.4	—	—	—	—	
046	18.2	22.3	—	—	—	—	—	—	2 meter shoal at beginning of segment
047	18.6	22.1	—	—	—	—	—	—	
048	17.2	—	—	—	—	—	—	—	
049	15.3	—	—	—	—	—	—	—	
050	14.5	—	—	—	—	—	—	—	2 meter shoal at mid segment.
051	13.9	—	—	—	—	—	—	—	
052	11.6	—	—	—	—	—	—	—	
053	12.1	—	—	—	—	—	—	—	
054	11.2	—	—	—	—	—	—	—	
055	9.5	—							

Line Number : 13 | Year : 1981 | gouge measurement In meters

SEGMENT	Fathogram Measurements: Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Sonograph Measurements: Gouge Width	Density C / D	Orientation (°T)	Sediment Cohesion	REMARKS
000	7.0	8.0	<.2	<.2	2	15/30	165/165	N S	course 000°T Range: 125 m
001	8.0	11.0	.2	.3	2	48/58	142/142	N/S	2 mult. gouges - 10 inc., 151°T, 32m wide,
002	11.3	17.5	<.2	.3	3	40/39	117/117	N/S	
003	13.8	23.2	<.2	.2	8	16/17	128/128	N/S	
004	16.1	24.0	.2	.2	12	45/44	97/97	N/S	
005	18.1	27.0	.3	.4	9	105/102	100/100	T ?	orientations are variable
006	20.0	28.4	.5	.8	7	160/158	113/113	C/R	mult. gouge - 8 inc., 016°T, 25m wide.
007	21.4	–	.8	.5	10	166/164	113/113	C/R	
008	23.1	–	1.2	1.0	7	124/123	112/112	C/R	3 small mult. gouges
009	24.1	–	1.5	1.2	15	114/113	115/115	C/R	many deep gouges (1.0m+)
010	26.8	31.8	1.3	1.4	10	125/135	128/128	C/R	different sub bottom reflector.
011	28.5	34.9	3.0	1.5	10	104/112	128/128	C/R	5 gouges over 2 m deep.
012	29.9	35.6	2.8	2.6	10	122/121	117/117	C/R	deepest incision and highest ridge are the same gouge (5.4 m relief)
013	33.3	36.5	1.0	.8	13	93/94	121/121	C/R	gouges become much smaller than previous segments.
014	34.9	37.7	1.3	1.1	17	100/101	118/118	T ?	
015	35.2	39.2	.9	.7	17	115/124	129/129	N/S	gouges are wider and very subdued on sonar.
016	34.8	–							

Line Number : 15 Year : 1981 gouge measurements in meters

	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
000	6.4	-	.5	.4	5	43/68	32/35	S N	Wet paper, rain, 125m
1	7.8	.		.3	15	74/31	34/37	S N	
2	8.2	—	.3	.2	15	36/55	23/26	S N	
3	8.5	—	.2	.2	12	67/86	36/39	S N	
4	9.3	-	.2	.2	7	48/52	52 55	S N	
	10.0	—	.2	.2	6	33/33	65/68	S N	
6	10.7		.2	.2	4	50 49	70/73	S N	
7	11.L	'	.2	.2	5	80/102	36/39	R C	(interpolate density)
8	12.3	—	.6	.5	8	44/43	100/103	R C	
9	13.3	—	.7	.7	12	44/43	80/83	R C	
10	14.2	-	.5	.4	3	44/43	80/83	R C	
11	14.s'	—	.6	.8	6	72/99	150/153	R C	
12	IL(3	—	.6	.9	7	125/135	130/133	R C	
13	16.8	—	.8	.5	10	138/149	130/133	R C	
14	18.0	—	.7	1.1	12	117/118	58/61	R C	
1<	19.0	—	L	7	8	112/113	120/123	R C	
16	19.8	'	.6	.7	0	77/75	70/73	R C	
17	21.?								

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Line Number : 31 Year : 1981 gouge measurements in meters

SEGMENT	Fathogram Measurements: Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Sonograph Measurements: Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
000	24.2	—	1.2	1.7	12	128/123	106/ 96	R/C	Range: 150m
001	23.2	—	1.4	1.0	6	170/167	094/ 84	R/C ?	6m bench (gougings heavier to seaward)
002	18.4	—	.8	.5	6	80/77	100/ 90	T ?	
003	17.1	—	.4	.5	3	57/55	070/ 60	S/N	Sediment waves (ripples) λ= 6 meters θ= 144°T
004	17.0	—	.2	.2	7	81/79	063/ 53	S/N	
005	17.0	—	.4	.3	5	106/102	075/ 65	T ?	
006	16.2	—	.3	.5	4	102/98	080/ 70	R/C ?	
007	15.3	—	.4	.9	6	53/53	092/ 82	R/C	
008	14.2	—	.3	.3	7	48/47	086/ 76	T ?	
009	13.1	—							

Line Number : 32 **Year :** 1981

gouge measurements in meters

SEGMENT	Fathogram Measurements: Water Depth (meters)	Fathogram Measurements: Reflector "A"	Fathogram Measurements: Gouge Depth	Fathogram Measurements: Ridge Height	Sonograph Measurements: Gouge Width	Sonograph Measurements: Density	Sonograph Measurements: Orientation (°T)	Sonograph Measurements: Sediment Cohesion	REMARKS
000	65.6	—	—	—	—	0/0	—	N	Possible Sand waves. Very SUBDUED θ=116°T h=<20 cm λ = 3 M Range 150m *
001	64.2	—	—	—	—	0/0	—	N	Possible sand waves and ripples. θ=118°T h=<20CM λ= 3 M
002	57.3	—	.5	.7	11	12/13	137/102	S/N	Range change to 200m. Possible shelf edge at * midsegment. Probably granular sediments.
003	53.6	—	1.1	.8	13	42/44	131/96	S/N	Gouges are large but subdued on sonar (sand + gravel) Most gouges are wide (>5 m).
004	54.3	—	.8	.5	8	41/41	125/90	S/N	
005	54.2	—	1.1	.4	15	57/62	134/99	S/N	
006	53.5	—	1.2	.7	18	59/58	120/105	S/N	
007	54.0	59.0	1.3	.7	19	48/52	136/104	S/N	1st subbottom reflector appears midway through segment 6-7.
008	54.5	58.3	2.5	1.3	35	61/70	140/120	S/N	350 m of sonar missing. Count adjusted.
009	54.3	—	2.5	.5	—	—	135/115	S/N	no sonar this segment.
010	54.7	—	2.5	.6	22	51/59	140/120	S/N	some BATS missing
011	55.0	—	2.0	1.3	18	46/48	131/111	S/N	
012	54.5	60.0	1.6	1.1	26	40/40	123/103	S/N	2 SUBBOTTOM REFLECTORS.
013	54.7	59.3	1.5	.8	40	32/32	127/107	S/N	
014	53.5	60.0	2.1	1.2	67	40/40	123/103	S/N	
015	52.8	58.0	3.0	1.3	27	41/43	131/111	S/N	
016	53.3	56.5	2.1	1.0	25	44/44	124/104	S/N	upper reflector surfaces at mid segment.
017	53.4	—	1.3	.7	21	39/41	129/109	S/N	gouges become much smaller at this point.
018	51.7	56.0	1.0	.8	22	48/48	127/107	S/N	2nd sub bottom reflector.
019	51.2	54.1	1.0	.5	—	—	—	S/N	no sonar this segment. 3rd Reflector begins this segment.
020	49.7	53.6	2.0	1.1	—	—	—	S/N	2nd reflector surfaces at mid segment.
021	47.3	53.8	1.5	.8	32	72/88	144/109	S/N	
022	47.7	54.0	.6	.6	15	78/85	134/99	S/N	
023	46.3	52.0	1.1	.8	15	85/93	135/100	S/N	
024	45.5	50.4	1.4	.6	20	76/79	132/97	S/N	
025	43.5	49.8	—	—	23	94/102	133/98	S/N	NO FATHOGRAM THIS SEGMENT. 3rd Sub bottom reflector surfaces.
026	43.6	—	1.3	1.4	39	93/101	134/99	S/N	
027	43.0	—	2.3	.7	34	126/137	135/100	S/N	Large Multi-gouges
028	41.5	—	1.8	1.9	11	114/131	140/105	S/N	

Line Number : 32 **Year : 1981** **gouge measurements in meters**

SEGMENT	Fathogram Measurements: Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Sonograph Measurements: Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
029	—	—	.5	1.0	15	95/109	139/104	S/N	Point 029 is not on Fathometer.
030	42.0	45.5	1.6	.8	17	72/78	136/101	S/N ?	Possibly 2 subbottom reflectors (4+5)
031	41.2	46.0	1.9	1.2	15	89/97	133/098	T ?	Gouging becoming rougher (sharper on sonar)
032	40.4	45.3	1.3	1.2	8	90/104	138/103	R/C ?	upper subbottom reflector surfaces (4)
033	42.0	44.9	.9	1.4	10	98/102	131/096	R/C ?	Gouges becoming smaller. subbottom reflector surfaces (5).
034	41.6	—	.5	1.6	11	96/100	129/094	R/C ?	
035	40.0	47.7	.7	.8	15	105/103	121/086	R/C ?	subbottom reflector begins (6)
036	39.4	42.4	1.4	.8	15	117/128	134/099	R/C ?	reflector surfaces mid segment.
037	38.2	—	.8	1.3	13	122/149	143/108	R/C ?	Steeply (relatively) dipping reflectors (offshore)
038	38.0	—	1.0	1.3	17	140/146	131/096	R/C ?	Steeply dipping reflectors.
039	37.1	—	1.5	1.2	8	151/148	122/087	R/C ?	axis of fold at ~ point 039 - steeply dipping reflectors now dip other way (onshore)
040	35.9	—	.7	1.3	9	121/139	139/104	R/C ?	steeply dipping reflectors
041	35.1	—	1.0	2.2	11	162/259	123/088	R/C ?	4 meter shoal at mid segment.
042	32.1	—	.7	.6	23	155/248	159/099	S/N ?	5.5 meter shoal at mid segment.
043	32.8	—	.7	1.0	12	124/179	155/095	R/C ?	
044	31.0	—	.9	.8	9	148/142	103/093	R/C ?	
045	31.3	—	.2	.4	19	64/64	091/081	S/N ?	4.5 meter shoal at end segment. Asymetric shape with steeper side offshore. STRANGE APPEARANCE.
046	28.0	—	.7	.8	8	104/101	115/090	R/C ?	
047	30.7	—	1.2	1.5	6	164/157	107/097	R/C ?	
048	29.6	—	1.2	1.7	7	157/151	106/096	R/C ?	
049	26.0	—	—	—	6	127/122	105/095	R/C ?	no fathogram this segment.
050	21.7	—	.8	1.0	5	201/193	105/095	R/C ?	
051	21.5	—							

Line Number : 33 **Year :** 1981 gouge **measurements** in meters

	Fathogram Measurements				Sonograph Measurements				θ = orientation λ = period
SEGMENT	**Water Depth (meters)**	**Reflector "A"**	**Gouge Depth**	**Ridge Height**	**Gouge Width**	**Density**	**Orientation (°T)**	**Sediment Cohesion**	T = transition **REMARKS**
000	6.4	—	<.2	<.2	2	8/11	152/157	N	N = non cohesive C = cohesive Range: 150m
001	8.5	—	<.2	<.2	25	11/12	137/142	N	sand waves λ 2.5m θ 005°
002	17.6	22.0	<.2	<.2	3	15/14	102/109		
003	18.2	21.5	.3	.4	5	103/100	115/120	T	break in slope - gougings heavier to seaward
004	22.2	—	.6	1.0	11	118/114	115/120	RC	
005	27.6	—	1.4	1.1	10	93/89	101/106	RC	
006	30.0	—	1.4	2.0	15	76/73	98/103	RC	
007	29.1	—	1.1	1.6	10	51/49	108/113	C (ex, on shoal)	Shoal / sand waves λ 1.5m θ 005°
008	30.4	—	1.4	1.3	11	107/103	111/116	RC	
009	41.5	43.0	1.6	1.7	5	78/75	100/105	RC	
010	36.7	40.5	1.0	.8	10	75/73	115/120	RC	
011	39.5	42.0	3.5	1.3	8	51/50	93/98	T ?	
012	43.0	46.0	3.0	.7	20	62/60	111/116	SN	Start of SUBDUED Gouge (appearance of outer line 32 type gouges)
013	45.0	47.6	2.2	1.5	10	66/63	105/110	SN	
014	44.5	50.0	3.2	1.7	12	68/65	110/115	SN	
015	47.0	50.5	1.5	1.7	10	34/33	122/127	SN	waves ? (lumpy bottom)
016	47.0	50.0	1.7	1.9	20	39/37	100/105	SN	
017	46.5	50.5	2.5	1.5	10	44/58	30/35	SN	
018	46.5	52.0	1.7	1.2	15	42/40	105/110	SN	
019	49.5	52.0	2.5	1.2	25	33/44	150/155	SN	
020	49.0	52.0	1.8	1.0	20	39/38	115/120	SN	
021	50.5	54.6	1.7	.9	45	13/19	26/31	SN	[illegible]
022	52.5	54.3							END LINE

Line Number : 34 Year : 1981 gouge measurements in meters

	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density ∠ D	Orientation (°T)	Sediment Cohesion	REMARKS
000	40.2	—	2.0	2.0	15	45/43	76/104	R C	
001	38.0	41.0	3.0	5.0	20	84/81	72/108	R C	
002	35.0	39.0	2.1	2.2	12	138/135	85/95	R C	
003	32.8	37.5	2.0	1.2	8	174/167	73/107	R C	33 m bench
004	39.0	42.0	1.6	1.2	20	68/65	70/110	R C	infilled gouges? Up other side of bench (depression)
005	35.5	41.5	1.6	1.0	12	94/90	78/102	R C	
006	32.6	39.0	2.3	1.5	10	90/86	71/109	R C	
007	32.5	36.0	1.8	1.2	10	147/144	86/94	R C	
008	28.5	33.5	2.3	1.5	10	186/182	60/120	R C	2° gouge θ = 74°
009	27.0	31.5	2.3	1.6	8	169/164	65/115	R C	
010	26.0	30.5	1.0	1.1	5	196/188	72/108	R C	
011	23.5	28.0	1.2	1.1	5	315/306	66/114	R C	
012	20.3	27.0	<.4	<.4	7	216/207	72/108	C	First reflector surfaces, 2nd reflector appears! 2m shoal w/gouging seaward
013	19.4	24.2	<.3	<.4	5	125/126	54/126	C	~30sec of SS record missing, not taken into density account.
014	17.6	20.0	<.2	<.2	8	58/60	48/132	T	
015	15.2	—	<.2	<.2	3	46/46	56/124	N	breaks in SS record
016	12.6	—	<.2	<.2	2	8/13	20/160	N	
017	9.9	—	<.3	<.2	2	9/11	36/144	N	
018	9.8	—	<.2	<.2	2	7/11	20/160	N	
019	5.5	—							END LINE

Line Number : 35 M **Year :** 1981 M **gouge measureme**

SEGMENT	(meters)		Depth	Height	Width	Density	(°T)	Cohesion	REMARKS
000	1.6	—	—	—	—	[illegible]	—	N	Range .50
001	4.0	1.0	<.2	<.2	2	[illegible]	117/117	N	
002	11.7	15.2	<.3	<.3	5	15/15	120/120	N	Funnybottom windows (Cohesive) in non cohesives.
003	13.0	19.0	<.3	<.3	1	16/16	124/124	N	hi relief in subbottom
004	14.8	19.0	<.3	<.3	5	13/13	117/122	N	
005	16.0	19.5	<.3	<.3	2	13/16	103/100	N	
006	16.5	21.0	<.3	<.3	2	25/56	133/160	N	
007	16.5	19.5	<.3	<.3	2	49/48	121/126	N	seaward dipping stratified section truncated at seafloor (erosional) - no holocene -
008	18.6	24.5	<.3	<.3	5	70/68	115/120	N	
009	20.1	24.0	<.3	<.3	6	74/72	115/120	N	gouges appear infilled?
010	21.5	27.5	.4	.8	1	133/128	110/115	T	
011	22.2	—	.7	.7	7	188/191	132/335	C	gouges are fresh looking.
012	21.5	—	.5	.8	1	229/238	132/335	C	No gouges, ice caught in the act
013	24.2	29.5	.7	.5	7	180/182	124/129	C	
014	26.1	33.5	.1	.8	2	136/133	121/126	C	
015	[illegible]		1.2	1.5	5	153/154	110/[illegible]	C	
016	[illegible]		1.0	.9	1	122/118	114/119	C	
017	32.0	36.6	1.0	1.2	4	125/121	114/117	C	
018	32.1	38.0	1.0	1.0	7	134/139	128/155	C	
019	32.6	40.0	.7	.1	6	110/114	128/154	C	
020	35.5	41.8	.6	.8	10	132/137	120/125	C	
021	45.1	42.5	.5	.1	15	71/70	110/124	C	
						60/			range
022	37.4	—	.6	.6	12	59/[illegible]	40/260	R C	
024	37.5	47.5	.7	.4	10	63/71	70/270	R C	
025	33.5	43.0	.4	.5	12	40/44	50/240	R C	
026	31.0	41.0	.6	1.2	12	95/93	60/170	R C	
027	30.5	40.2	.0	1.0	20	105/107	65/125	R C	
028	33.1	30.5	1.4	1.0	11	141/137	165/165	R C	

Line Number : 35 (con't) **Year :** 1981 gouge measurements In meters

SEGMENT	Fathogram Measurements: Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Sonograph Measurements: Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
029	33.5	37.7	1.0	1.0	15	165/162	60 300	R C	strong sub bottom
030	30, 6	36.2	1.1	1.0	c	146/143	62/302	R C	
031	28.0	33.8	2.0	.8	10	182/177	66/306	R C	
032	26.7	32, 0	1.0	.8	7	212/208	58/298	R C	sub bottom coming up
033	25.5	29.5	1.0	.7	5	185/179	65/305	R C	
034	22.5	–	.7	.6	5	185'//79	66/301	R C	
035	21.5	–	.5	.7	7	158//155	62/302	T	
036	20,0	–	.2	.5	3	135//140	52/29 2	S C	BSR(?) Change course 240°
037	19.0	'	<.2	<.2	15	65/62	72/3 12	S C	Patchy c/c 260
038	18.4	–	<.3	.7	7	17/18	52/312	S N	
039	15.8	–	<.3	.4	6	22/23	50/310	S N	Patchy
040	13.5	–	<.3	<.3	2	73/26	42/302	S N	
041	11.0	–							END LINE

1 km?

Line Number : 36 Year : 1981

gouge measurements in meters

	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density C D	Orientation (°T)	Sediment Cohesion	150m range REMARKS
000	5.0	—	<.2	<.2	1	2/3	21/78	S N	Funny bottom (still clay) & sand (?)
001	7.3	—	—	—	—	0/0	—	S N	
002	9.2	—	<.2	<.2	1	1/1	14/121	S N	funny bottom
003	12.3	—	<.2	<.2	1	10/11	44/101	S N	
004	13.7	—	.3	.3	4	26/25	75/110	S N	
005	15.6	—	<.3	<.2	4	34/35	50/107	S N	Gouging in subbottom ; sand gouging
006	16.9	—	.3	.3	4	25/25	55/112	S C	
007	17.7	—	.2	.2	7	78/79	55/112	S C	
008	18.5	—	.2	.3	5	23/23	62/112	S N	
009	20.1	—	<.2	<.2	5	50/49	62/112	S N	
010	21.2	—	.2	.3	6	80/92	40/39	S N	
011	21.6	—	.2	.4	6	126/137	43/114	R C	
012	22.8	—	.5	.5	10	196/204	52/111	R C	1 m shoal/bench - gougings heavier to seaward
013	26.2	—	1.2	1.1	8	176/172	118/143	R C	
014	—	—	.6	.6	5	109/105	102/127	R C	
015	30.5	33.5	1.0	1.2	5	119/120	123/148	R C	gouges appear SUBDUED.
016	34.0	37.2	.7	.5	5	92/90	120/145	R C	
017	34.0	39.5	1.0	1.0	8	69/66	105/130	R C	
018	35.5	40.2	.6	.4	6	82/80	118/143	R C	
019	35.6	40.5	.8	1.3	7	102/102	90/115	R C	
020	35.7	39.3	.9	1.0	6	111/108	117/142	R C	
021	36.5	41.0	.6	.8	5	136/131	70/138	R C	
022	38.4	40.0	.8	.5	6	89/86	65/120	R C	gouges appear fresh again.
023	39.5	42.0	1.5	1.4	10	79/76	118/278	R C	undulating sub b
024	37.1	39.1	1.4	.9	10	97/100	125/285	R C	
025	35.6	39.[illegible]	.4	.5	5	181/183	125/295	R C	
026	34.5	39.0	.7	1.6	8	186/188	125/285	R C	
027	34.4	38.0	.8	.9	8	165/190	138/298	R C	
028	34.2	40.0	.7	.6	12	164/179	135/298	R C	

Line Number : 36 (con't) M Year : 1981 M

gouge measurements in meters

	(meters)	A	Depth	Height	Width	(°M)	(°T)	Cohesion	REMARKS
029	[illegible]	71.0	.10	.5	10	118/117	124/284	RC	CS 160°
030	34.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	RC	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	RC	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	RC	
033	[illegible]	56.0	.6	.4	5	175/177	123/283	RC	extrapolat in (140 gouges in 3/4 distance)
34	31.6	[illegible]	.8	.6	7	180/220	[illegible]	RC	"
			[illegible]	.0	0	184/524	140/300	RC	
36	29.5	—	.5	.5	12	235/244	130/290	RC	many multi gouges
37	27.0		[illegible]	.7	[illegible]	1310/301	115/275	RC	↓
[illegible]	[illegible]		[illegible]	[illegible]	10	[illegible]	[illegible]	RC	
		—	.7	.5	10	204/198	140/180	RC	
40	24.7		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	RC	[illegible] bench
(41) Not real	24.3	—	—	—	—	—	—		step sample
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	229/302	152/312	RC	outcrop stiff silty clay?
43	22.2	—	<.3	<.3	5	169/164	115/287	RC	C/C 172°
44	21.5	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	RC	
[illegible]	[illegible]		[illegible]	.7	5	155/152	122/282	RC	structural scour's C/C 160-165°
	|								
46	18.8	—	<.2	<.2	3	53/54	127/287	SN	2 m bench - gouging heavier to seaward
47	17.5	—	<.2	.4	4	33/36	135/300	SN	
48	17.0	—	.2	.3	6	64/[illegible]	[illegible]	SN	
49	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SN	
50	12.5	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SN	
51	11.4		[illegible]	[illegible]	[illegible]	117/114	[illegible]	SN	
52	[illegible]								END LINE

Line Number : 37 Year : 1981 gouge measurements in meters

SEGMENT	Fathogram Measurements: Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Sonograph Measurements: Gouge Width	Density 2/b	Orientation (°T)	Sediment Cohesion	REMARKS
000	8.0	—	.2	.2	3	24/25	132/132	S N	RANGE 150 m
001	13.9	—	.3	.5	4	141/147	50/50	SN	(Break in S/S record) (Winding)
02	15.6	—	1.0	.7	5	196/192	120/120	SN	
03	17.2	—	.7	.9	7	199/195	120/120	SN	
04	19.5	—	1.0	1.0	6	182/177	124/124	SN	
05	20.6	—	.9	.7	5	198/190	108/108	SN	
06	21.7	24.0	1.1	1.1	7	171/166	124/124	SN	
07	23.2	25.8	1.7	1.1	6	191/187	~120/120	RC	Winding
08	23.8	26.5	2.5	1.0	18	211/205	115/115	RC	
09	25.2	28.5	1.3	1.2	6	127/123	114/114	RC	
10	25.5	29.0	2.0	1.5	9	122/117	100/100	RC	
11	27.0	30.0	1.7	1.6	8	151/145	110/110	RC	
12	28.2	32.6	2.4	1.8	8	165/158	112/112	RC	
13	28.0	31.6	2.0	1.3	6	93/91	121/121	RC	
14	29.0	33.8	2.6	1.4	13	156/150	120/120	RC	
15	29.5	33.0	2.0	1.5	—	—	—	—	NO SONAR
16	30.7	33.3	1.6	1.2	10	132/137	130/130	RC	C/C 270°
17	31.5	34.0	1.7	1.0	12	134/154	38/308	RC	C/C 320°
18	31.7	34.0							circling to end line

Line Number : 38 **Year : 1981** gouge **measurements** in meters

SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density C / D	Orientation (°T)	Sediment Cohesion	REMARKS
	Fathogram Measurements				Sonograph Measurements				
000	5.5	—	<.2	<.2	1	2/3	26/63	S N	Range 150m
001	9.7	—	<.2	<.2	1	6/7	42/80	S N	ripples
002	11.6	—	<.2	<.2	1	33/110	0° / 38°	S N	c/c 038° θ=139°T λ=3m h=<.2
003	14.2	—	.2	<.2	4	61/98	21°/ 59°	S N	truncated beds
004	16.6	—	<.2	<.2	5	91/105	42/ 30°(?)	S N	Bed } much winding
005	16.8	—	.3	.2	4	123/134	45/ ~15(?)	S N	
006	18.7	—	.3	.4	5	145/142	120/158	T	Bed 5 c/c 38°
007	20.2	—	.3	.5	10	120/115	75/113	R C	
008	21.7	—	.5	.5	10	189/181	78/116	R C	Mud
009	22.0	—	1.0	1.0	15	259/249	78/116	R C	Bed 4
010	25.2	—	1.0	.7	12	185/178	78/116	R C	
011	27.2	—	1.7	1.5	10	170/172	55/93	R C	
012	28.0	—	2.0	1.4	10	158/152	78/116	R C	
013	28.6	—	2.0	1.6	8	120/115	72/110	R C	
014	30.0	—	1.7	1.3	50	129/124	80/118	R C	clay
015	31.0	—	1.8	1.7	10	151/145	105/143	R C	Bed 1 truncates at surface
016	32.3	35.0	1.7	1.0	10	144/138	75/113	R C	Bed 3 appears
017	32.5	35.6	1.7	1.0	12	133/128	112/150	R C	
018	33.0	36.5	1.5	1.0	12	170/163	76/114	R C	
019	34.0	36.4	2.0	1.0	15	171/164	105/143	R C	
020	35.0	38.5	3.2	2.1	25	87/84	110/148	S N	BSR(?) A second bed appears(?) Bed 2 SONAR GOUGES SUBDUED
021	36.1	40.0	1.7	1.2	10	101/97	105/143	S N	
022	36.6	39.4	2.5	1.4	25	107/104	65/103	S N	c/c 038
023	36.4	40.0	2.8	1.7	25	148/145	85/123	S N	
024	37.5	40.7							Bed 1 mud